AUSTIN COVE ESTATE, SOUTH YUNDERUP

LAKE MANAGEMENT PLAN

Prepared for

Satterley Property Group
18 Bowman Street
SOUTH PERTH WA 6150

Report No. J06002b
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trading as Bayley Environmental Services

Note: All land identified in this document or any plan submitted with it for use for public purposes, including public open space, conservation category wetland, vegetation buffers, school sites, drainage areas and the like, has been identified for these uses in accordance with standard practice, relevant policies or at the request of the relevant agencies. The identification of land for these purposes does not necessarily imply that any or all such land will be ceded free of cost or that any use is necessarily shown at its highest and best use.

EXECUTIVE SUMMARY

The proposed Austin Cove Phase 2 development is located on 271ha of urban-zoned land east of the Peel Inlet and about 11km east of Mandurah. The site is immediately south of the South Yunderup 100-year floodway of the Murray River and immediately west of the planned Perth-Bunbury Highway Peel Deviation.

Satterley Property Group (Satterley) proposes to develop about 2,350 residential lots in Phase 2. A feature of the development will be the creation of a 27ha central open space incorporating a 16.6ha lined lake to serve landscape, active and passive recreation, irrigation, flood management and amenity functions. The lake is located in the eastern part of the Phase 2 area with its long axis running generally north-south. The lake measures approximately 1.6km in length from north to south. At its nominal full level of 2.5m AHD, the lake will have a total volume of approximately 442,000 m^3.

The feature lake and its surrounding POS are intended to be a major focal point in both visual and practical terms for the Austin Cove Phase 2 development. The highest lot densities will mostly be concentrated around the southern part of the lake, along with the village centre including cafés, boardwalks and other public facilities.

The reserve and lake will serve a major recreation function within the development. At 16.6ha in area and 1.6km in length, the lake is large enough to accommodate recreational unpowered boating such as sailing and rowing.

Swimming will not be encouraged in the lake, as the water quality will not be maintained at a level suitable for primary contact recreation. Signs will be erected around the lake perimeter to advise against swimming.

The POS areas around the lake will provide space for a range of active and passive recreational activities including walking, picnicking, bird watching, kick-about football and soccer. It is envisaged that facilities within or near the POS will include picnic tables and chairs, barbecues, shade structures and cafés.

A range of different direct lake edges will be applied around the lake, including walls, turf, planting beds, boardwalks and promenades.

The lake will be lined and located in fill with its water level above the AAMGL. The lake will have a constant water level (within a fluctuation of about +/-20cm), maintained by rainfall and roof runoff in winter and by pumped bore water as required in summer. Water will be removed from the lake by evaporation and winter overflow. In early summer, when the salinity of the lake is below 1,600mg/L TDS, lake water will be used for irrigation. The salinity of the lake will vary between about 900 and 1,800 mg/L TDS in most years, reaching a maximum of 2,200 mg/L in the first year after filling.

The lake will receive overflow from infiltration basins within its catchment from storms in excess of 5-year ARI. The lake will overflow at its southern end into the Multiple Use Corridor (MUC) that extends from the lake to the south-west corner of the development area, where it discharges into a degraded wetland area within the floodway. Water flowing along the MUC will pass through a series of streams, ponds and reed beds that will further purify the water before it is allowed to leave the site.

Roof runoff from a 17ha catchment will be captured and directed via a separate pipe system to the lake in order to assist winter flushing and salinity control in the lake and enhance its usefulness for irrigation. Modelling of the lake and surrounding POS indicates that the proposed size is the optimum in terms of rainwater capture, irrigation efficiency and overall groundwater demand.

Irrigation water for the whole of Austin Cove Stages 1 and 2 as well as other areas including the South Yunderup Sports Club oval will be drawn from the feature lake and the irrigation lake. During early summer, when the salinity of the feature lake is below the bore water salinity of 1,600mg/L TDS, this lake will be used for irrigation. Later in summer when the feature lake salinity rises, irrigation water will be drawn from the dedicated 2ha irrigation lake, which will be refilled from the bore.

The lake will be constructed in two sections, with the first (6.8ha) section north of the bridge being completed in about year 3 of the project and the second (9.8ha) section south of the bridge following about two years later. The two stages will be separated by a staging bund that will ultimately be removed to create a single water body.

The average annual water balance of the lake is estimated as follows:

Component (all units in ML/year unless stated otherwise)	**Value**	**% of total**
Rain water input	141	32%
Groundwater input	173	39%
Roof water input	125	28%
Total Inputs	**439**	100%
Evaporation output	-229	52%
Irrigation output (begins about 2011)	-118	27%
Overflow	-93	21%
Total Outputs	**-439**	100%

1 The calculation starts after Stage 1 of the lake development is finished (year 3 of the project) and Stage 2 completed in year 5 of the project.

The lake will receive phosphorus and other nutrients from inputs of bore water, rainfall and atmospheric fallout, water birds and occasional (less than once every 5 years) stormwater overflow from infiltration swales. Nutrients will leave the lake water via removal of water for irrigation, winter overflows and by immobilisation in the bottom sediments (under certain conditions, phosphorus released from the sediments may form a significant source of internal phosphorus loading).

The largest source of phosphorus (the key limiting nutrient in fresh waters) is expected to be waterbirds such as ducks, which may obtain much of their food from outside the lake and then defecate in the lake. The number of birds using the lake, the proportion of their food sourced from outside, the proportion of their faeces entering the lake and the nutrient content of the faeces are all difficult to accurately estimate. However, the numbers used in the modelling are believed to represent an upper estimate of the likely nutrient inputs from this source.

Overpopulation and other bird-related problems are only likely to arise if regular feeding of birds takes place at or near the lake. This can best be combatted by a combination of public education (by leaflets etc) and signage around the lake requesting people not to feed the birds.

Modelling using the one-dimensional hydrodynamics model DYRESM coupled with the aquatic ecological model CAEDYM suggests that the water quality of the lake will be high and suitable for secondary contact recreation, with phosphate (PO_4) concentrations below 0.035mg/L and chlorophyll-*a* below 2.6 μg/L. Chlorophyll-*a* is a commonly used indicator of algal density; values of 10μg/L or more are commonly considered to indicate algal bloom conditions.

The water nutrient and chlorophyll-*a* concentrations in the lake were modelled over a representative 4.5-year period beginning in June 2012 when both parts of the lake have been constructed and the lake is full, incorporating actual monthly rainfall for the years 1987 to 1991 and evaporation data for 2002 to 2006. The Total Phosphorus concentration is expected to be low throughout the year, with a maximum of about half of the Freshwater Guideline of 0.06mg/L. Nitrogen levels are also predicted to remain low throughout the year. Chlorophyll-*a* levels in the lake are expected to remain below 2.2μg/L throughout the year. The conclusion from the modelling is that the water quality of the lake is expected to be high throughout the year.

The modelling indicates that stormwater inflow from a 10-year ARI storm will produce a short-term spike in both phosphate and chlorophyll-*a* levels, but that the latter will not reach bloom concentrations and both will return to normal levels by the next winter.

Further modelling of lake circulation and mixing was carried out using the three-dimensional hydrodynamic model MIKE-3. The purpose of this modelling was to further investigate whether the lake would be well mixed from end to end as well as top to bottom, whether areas of poor circulation might cause heating and algal growth, and whether stratification was likely to occur.

The results of the MIKE-3 modelling indicate that:

- The circulation in the lake will be predominantly driven by the wind. Autumn is predicted to have the least energetic circulation due to the generally lighter winds.

- Density-driven currents, due mainly to differential heating of the lake, will also influence the circulation but this effect is secondary to wind as the spatial variations in temperature and salinity are relatively small. The effect of the density-driven currents will only be apparent during low-wind periods in summer.

- Most of the time the lake will be well mixed vertically. Some thermal stratification is predicted during daylight hours, but convection will cause the lake to cool and mix on most nights.

- No significant salinity or temperature stratification is predicted.

- The horizontal and vertical variations in nutrient concentration are predicted to be minimal.

The water quality of the feature lake will be managed to ensure that pathogenic micro-organisms are not present in sufficient numbers to cause health problems through incidental contact with the lake water. The water quality will be maintained at a level suitable for secondary contact recreational waters, as set out in the *Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters* (ANZECC, 2000).

This standard of water quality will enable the lake to be safely used for water-based activities that involve “incidental” contact with the water, including splashing, wading and occasional full immersion. The types of use included in this category include recreational boating, rowing, canoeing, sailboarding, model boating and wading. They do not include full (primary) water contact activities such as swimming and diving.

The lake water quality and hydrology have been designed so as to be as nearly as possible maintenance-free, with the only normal management inputs being monitoring of the automatic systems that control water levels and irrigation outflows, plus periodic monitoring of water quality and ecological state. The physical structures of the lake and ancillary equipment will require periodic maintenance in accordance with equipment specifications. These maintenance activities will be carried out by the Satterley Property Group until at least ten years after practical completion of the lake or until the completion of Austin Cove Phase 2, whichever is the later, after which they will be handed over to the Shire of Murray.

A comprehensive monitoring programme will be implemented at the lake. The programme will include:

- continuous recording of lake inflows and outflows;
- monthly to six-monthly monitoring of water quality in the supply bore;
- opportunistic monitoring of the quantity and quality of stormwater overflow reaching the lake;
- monthly monitoring of algal and microbial populations in the lake;
- quarterly to six-monthly monitoring of other water quality parameters in the lake including nutrients, metals, hydrocarbons and physical parameters; and

- regular visual monitoring of algae, aquatic plants, fish, water birds and insects.

The results of the monitoring will be reported annually to the Shire of Murray, the DEC and the DoW. The monitoring results will also form the basis of a Performance Review Program designed to confirm and/or update the predictions of the modelling and to optimise the water use efficiency, water quality and public amenity.

Contingency response strategies have been developed in case monitoring reveals a deterioration in any aspect of the lake water quality or other parameters. The contingency responses available are detailed in Section 8.0.

Costings for lake management, maintenance and monitoring have been developed and are detailed in Section 9.0. A summary of the monitoring programmes, contingency responses and costings is presented in Table E1.

Satterley Property Group will implement and fund the Lake Management Plan for at least ten years after completion and filling of the lake. At the end of this period, the ownership and responsibility for management of the lake and central POS will be transferred to the Shire of Murray.

Satterley Property Group will establish a funding mechanism in consultation with the Shire of Murray sufficient to cover the ongoing projected costs of lake monitoring, management and maintenance, as detailed in Section 9.0, following the handover of the lake to the Shire. This funding mechanism is envisaged to be based on a Specific Area Rate levied by the Shire of Murray on lot owners within Austin Cove. Satterley will continue discussion with the Shire of Murray over the form, scale and implementation of the funding mechanism.

Table E1 Summary of Monitoring Programmes, Criteria, Contingency Responses and Costs

Parameter	*Source/Method*	*Frequency*	*Criteria*	*Contingency Response*	*Average Annual Cost*
Inflows and Outflows Bore inflows Irrigation outflows	Pump operating records	Recorded continuously Audited annually	Significant excess of inflows over outflows	Investigate possible leaks	$450
Overflow volume	Water level recorder on overflow weir	Recorded continuously Audited annually			$450
Rainfall and evaporation	Bureau of Meteorology / Dept of Agriculture	Obtained annually			$150
Bore Water Quality pH Salinity (TDS) Total & dissolved Iron Hardness (as $CaCO_3$) Total P Reactive P Total Kjeldahl Nitrogen Nitrite + Nitrate Ammonia-N Heavy metals: Al, As, B, Cd, Cr, Cu, Fl, Pb, Mn, Ni, Zn	Water supply bore(s)	**First Year:** • Dec, Mar, Sept, May **Subsequent Years:** • Mar, Sept **Salinity only:** • Monthly Sept-May (first year)	Pre-development bore water quality and ANZECC (2000) Guidelines for Secondary Contact Recreation Waters	Notify Shire of Murray. Investigate causes and effects. Treat bore water before discharge into lake. Identify alternative water source. Shandy bore water with scheme water for irrigation.	**First Year:** $975 collection $1200 analysis **Subsequent Years:** $300 collection $600 analysis
Stormwater Inflow Quality pH, EC, TSS Hardness (as $CaCO_3$) TP, FRP, NO_X, TKN, NH_4-N Heavy metals: Al, As, B, Cd, Cr, Cu, Fl, Pb, Mn, Ni, Zn Faecal coliforms, enterococci Total Petroleum Hydrocarbons (TPH)	Inflow points (15): grab samples and/or rising stage samplers	Opportunistic – average once every 5 years	ANZECC (2000) Guidelines for Secondary Contact Recreation Waters	Notify Shire of Murray. Sample lake. Investigate source(s) of contamination. Clean infiltration basins. Enlarge basins. Increase street cleaning frequency. Increase public education. Seek prosecution of persons found illegally discharging contaminants.	$240 collection $880 analysis

Parameter	***Source/Method***	***Frequency***	***Criteria***	***Contingency Response***	***Average Annual Cost***
Lake Water Quality Total P Reactive P Dissolved Organic P Particulate Organic P Total Kjeldahl N Nitrite + Nitrate Ammonia-N Dissolved Organic N Particulate Organic N Dissolved Organic Carbon Particulate Organic Carbon Total & dissolved Iron Hardness (as $CaCO_3$) Heavy Metals: Al, As, B, Cd, Cr, Cu, Fl, Pb, Mn, Ni, Zn Faecal coliforms, enterococci Chlorophyll-*a* Phaeophytins OC & OP pesticides TPH	Lake edge sampling locations (4)	**First Year:** • Dec, Mar, Jun, Sept **Subsequent Years:** • Mar, Sept **Microbial and chlorophyll:** • Dec, Mar, Jun, Sept (first and second years) • Monthly (subsequent years) Plus event sampling after stormwater inflows (average once every 5 years)	ANZECC (2000) Guidelines for Secondary Contact Recreation Waters and ANZECC (2000) Guidelines for Irrigation Water Quality	Notify Shire of Murray. Close lake to contact recreational use. Re-sample lake. Reopen lake for contact recreation when water quality meets guidelines. Control bird numbers to reduce faecal inputs. Clean and/or enlarge stormwater basins. Seasonal or permanent closure of lake to contact recreation. Shandying of lake water with scheme water for irrigation.	**First Year:** $7400 collection $6560 analysis **Second Year:** $3800 collection $4180 analysis **Subsequent Years:** $3800 collection $7800 analysis
Temperature pH Salinity (EC) Turbidity/Light Penetration Dissolved oxygen Redox potential	Lake profile locations (4) from dinghy				
Algae	Visual surveillance	Six monthly	Excessive algal growth or Chlorophyll-*a* >10μg/L	As for water quality.	$150

Parameter	***Source/Method***	***Frequency***	***Criteria***	***Contingency Response***	***Average Annual Cost***
	Chlorophyll-*a* monitoring	As for lake water quality		Algal harvesting. Algaecides. Barley straw/Frogmat. Ultrasonic controllers. Colouring agents. Phosphorus precipitation. Macrophyte plantings.	
Aquatic Plants	Visual surveillance Public correspondence	Six monthly Continuous	Excessive aquatic plant growth	Plant harvesting. Colouring agents. Herbicides (subject to safety in receiving environment).	\$150 \$150
Fish	Visual surveillance Public correspondence	Six monthly Continuous	Excessive fish numbers or presence of nuisance species	Netting. Electric stunning. Draining of lake.	\$150 \$150
Birds	Visual surveillance Public correspondence	Six monthly Continuous	Occurrence of bird feeding Excessive bird numbers Excessive nutrient levels		\$150 \$150
Insects	Visual surveillance Public correspondence Mosquito larvae counts	Six monthly Continuous Monthly Jan-Aug Weekly Sep-Oct Fortnightly Nov-Dec	Excessive mosquitoes or midges Public complaints of insect nuisance >50 live mosquito larvae per 250m at two adjacent locations or 4 total locations on 2 successive occasions	Cleaning of GPT, basins etc. Thinning in-lake vegetation. Lake modification. Chemical control (larvicides). Biological controls (insectivorous fish, lemon grass etc.) Passive controls (lighting etc.)	\$150 \$150 \$12000
Estimated total annual cost	**- Year 1** **- Year 2** **- Subsequent Years**				**\$31,650** **\$24,400** **\$28,000**

Table E2 summarises the compliance of this document with the requirements of the Scheme provisions for the Lake Management Plan.

Table E2 Compliance with Scheme Provisions

Scheme Provision	***Compliance***
(i) Compliance with design objectives in the UWMS	All relevant design objectives and features of the UWMS are reflected in the LMP.
(ii) A description of the dimensions, features, purpose and function of the lake	See Section 2.0
(iii) A description of the function of the lake during significant storm events, including details about the management of overland flow from that water body to the water dependent ecosystems	See Sections 2.2.1 and 3.1
(iv Details regarding the volumetric capacity of the lake and the proposed means for maintaining water levels	See Sections 2.3 and 3.2
(v) Details of predicted source water, including associated catchment requirements - as well as groundwater availability, replenishment capacity and sustainability	See Section 2.5
(vi) Details of water quality maintenance proposals (such as algal management) including circulation through connection to, and routine use within, the irrigation system for open space areas within the development area of the subject land	See Sections 3.0 and 4.0
(vii) Management of disease vector and nuisance insects such as mosquitoes and midges	See Section 5.5
(viii) Details regarding construction (to a fully functional capability) of the water body and the preservation and protection of the surrounding environment and water dependent ecosystems during this process	See Section 2.4
(ix) A detailed 'Management and Maintenance Schedule' for the lake, covering a period of 5 years and commencing from time of its practical completion. This Schedule shall include a monitoring and reporting program and contain details in respect to 'whole of life' costings for the management and maintenance of the water body (for a 20 year cycle), the establishment and ongoing operation of a 'strata reserve fund' to meet those total costings, and the transfer in perpetuity (after 5 years) of management and maintenance responsibility to the Shire of Murray	See Table E1 and Sections 6.0, 7.0, 9.0 and 10.0
(x) A monitoring program, including definition of performance criteria and analysis procedures, to demonstrate whether the management objectives are being met	See Section 7.0
(xi) Contingency measures to be implemented in the event that pollution and nutrient concentrations exceed agreed performance targets	See Section 8.0
(xii) Identification of responsibilities and timeframes for implementing the Lake Management Plan	See Section 10.0

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1.0 INTRODUCTION

1.1 Outline Development Plan

The Austin Cove Outline Development Plan (ODP) area covers approximately 526ha within the Shire of Murray, bounded by South Yunderup Road to the north and the future Perth-Bunbury Highway to the east. The development area is zoned ‘Urban’ under the Peel Region Scheme and ‘Special Development’ under the Shire of Murray Town Planning Scheme No. 3.

The Austin Cove ODP represents a significant advancement with regard to planning, environmental and sustainability objectives. The ODP allows for the creation of a residential development focused around a system of connected open space areas serving conservation, drainage, recreation and amenity functions. As well as approximately 2,500 residential lots, the ODP provides for 71.6ha of open space within Phase Two, representing 29.4% of the gross developable area. The development is focused on the proposed central open space and lake area. The ODP is shown on Figure 1.

1.2 Draft Approval Conditions

The Statutory section of the Austin Cove Outline Development Plan sets out the following requirements to be addressed in the Lake Management Plan:

‘*Prior to final approval of the Outline Development Plan, a Lake Management Plan for the feature lake (central open space) shall be prepared to the satisfaction of the Shire of Murray, on advice from the Department of Water, to ensure that water quantity and quality, and the management and maintenance of the water body, is at sustainable and appropriate levels*.

‘The Lake Management Plan shall include but is not limited to the following:

(i) Compliance with design objectives in the UWMS;

(ii) A description of the dimensions, features, purpose and function of the lake;

(iii) A description of the function of the lake during significant storm events, including details about the management of overland flow from that water body to the water dependent ecosystems;

(iv Details regarding the volumetric capacity of the lake and the proposed means for maintaining water levels;

(v) Details of predicted source water, including associated catchment requirements - as well as groundwater availability, replenishment capacity and sustainability;

(vi) Details of water quality maintenance proposals (such as algal management) including circulation through connection to, and routine use within, the irrigation system for open space areas within the development area of the subject land;

(vii) Management of disease vector and nuisance insects such as mosquitoes and midges;

(viii) Details regarding construction (to a fully functional capability) of the water body and the preservation and protection of the surrounding environment and water dependent ecosystems during this process;

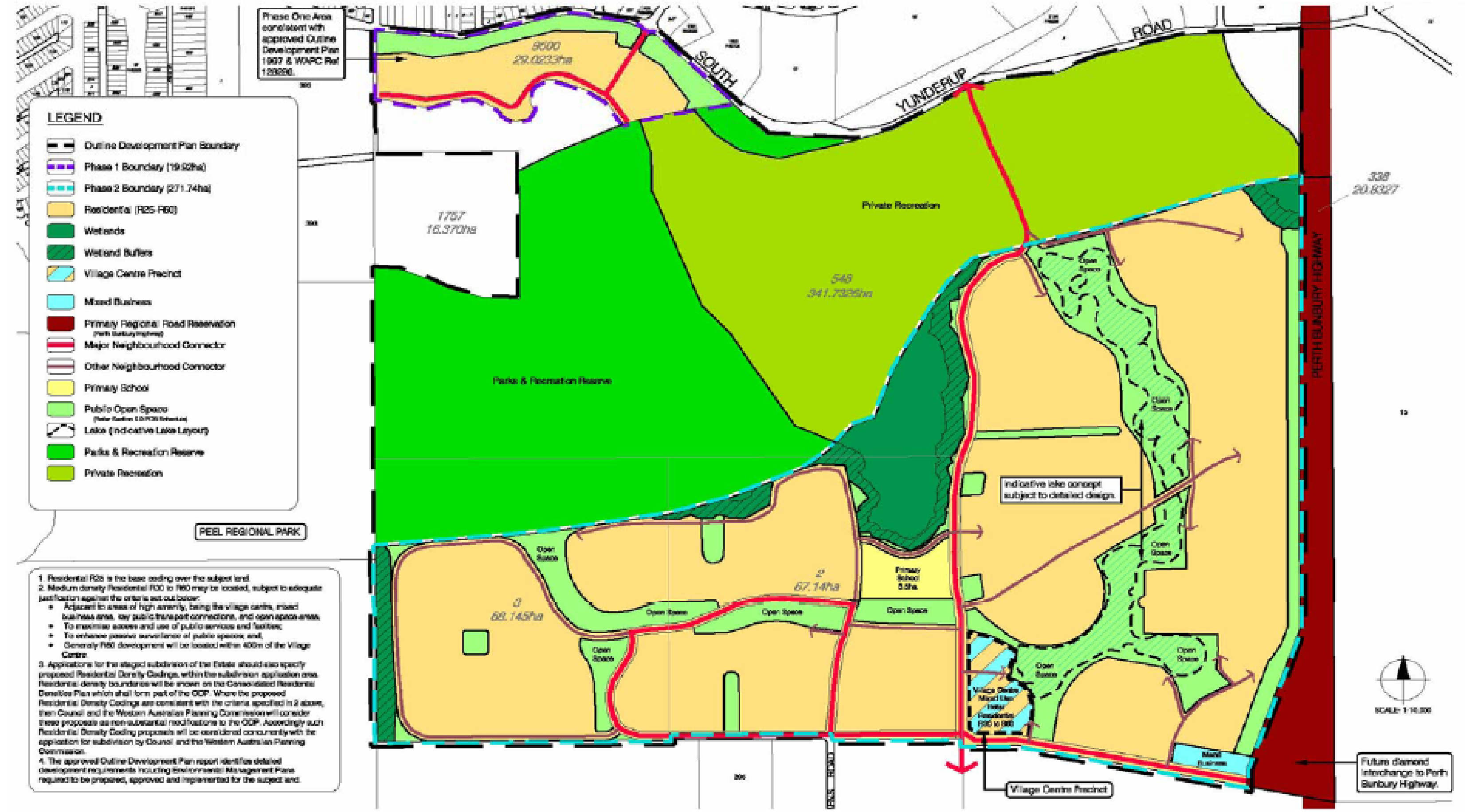
(ix) A detailed 'Management and Maintenance Schedule' for the lake, covering a period of 5 years and commencing from time of its practical completion. This Schedule shall include a monitoring and reporting program and contain details in respect to 'whole of life' costings for the management and maintenance of the water body (for a 20 year cycle), the establishment and ongoing operation of a 'strata reserve fund' to meet those total costings, and the transfer in perpetuity (after 5 years) of management and maintenance responsibility to the Shire of Murray;

(x) A monitoring program, including definition of performance criteria and analysis procedures, to demonstrate whether the management objectives are being met;

(xi) Contingency measures to be implemented in the event that pollution and nutrient concentrations exceed agreed performance targets; and

(xii) Identification of responsibilities and timeframes for implementing the Lake Management Plan. '

This Lake Management Plan addresses these requirements and sets out a comprehensive, integrated management framework for the Austin Cove Lake.



Data Source: Chappell Lambert Everett 2006.

Figure 1 Austin Cove Outline Development Plan

2.0 DESCRIPTION OF LAKE

2.1 Location and Layout

The Central Open Space covers approximately 27 hectares, of which 16.6ha is the lake and 10.4ha is the surrounding open space area. The lake is located in the eastern part of the Phase Two area with its long axis running generally north-south (Figure 1). The lake measures approximately 1.6km in length from north to south. At its nominal full level of 2.5m AHD, the lake will have a total volume of approximately 442,000 m^3.

A 2ha section of the lake will be separated hydraulically from the main body of the lake and used as a buffer storage for irrigation water during periods when the main lake is too saline to use for irrigation. This irrigation lake will be maintained with sub-potable brackish (1,600mg/L TDS) groundwater.

2.2 Lake Functions

2.2.1 <u>Urban Water Management</u>

The feature lake will act as part of the stormwater management system by accepting overflow drainage from primary swales within its catchment from storms larger than 5 year ARI. Details of the overflow volumes predicted to enter the lake are given in Section 3.1.

The primary infiltration swales within the lake catchment are designed to accommodate all storm runoff from storms up to 5 year ARI before overflowing to the lake. This is a greater capacity than swales outside the lake catchment, which are designed to overflow in storms of more than 1 year ARI. This is because the lake is an enclosed water body with a limited capacity to tolerate the nutrients carried in stormwater.

Water will also enter the lake from roof runoff, direct rainfall and the dedicated water supply bore (see Section 3.1). The lake will overflow regularly during winter at its south-west corner into the multiple use corridor.

2.2.2 <u>Active and Passive Recreation</u>

The feature lake and its surrounding POS are intended to be a major focal point in both visual and practical terms for the Austin Cove Phase 2 development. The highest lot densities will mostly be concentrated around the southern part of the lake, along with the village centre including cafés, boardwalks and other public facilities.

The reserve and lake will serve a major recreation function within the development. At 16.6ha in area and 1.6km in length, the lake is large enough to accommodate recreational unpowered boating such as sailing and rowing.

The Mandurah Dragon Boat Club, Rowing WA and Canoeing WA have all expressed interest in the possible use of the lake as a venue for training and/or racing in their organisations. The secretary of one organisation noted that both of their current training venues – the Mandurah Offshore Fishing & Sailing Club and the Murray River at Ravenswood – are becoming unsafe because of the increasing number of large power boats using the waterways.

Satterley Property Group will continue discussions with these and other potential users of the lake, and will explore opportunities to modify the lake design where appropriate to maximise its usefulness for these pursuits.

As well as organised activities such as these, the lake will accommodate many other active and passive uses including informal canoeing and rowing, model boating and sailing. Markers may be located in the lake to designate an informal rowing course. Small launching jetties and/or pontoons will be provided to facilitate the launching of small water craft.

Swimming will not be encouraged in the lake, as the water quality will not be maintained at a level suitable for primary contact recreation. Signs will be erected around the lake perimeter to advise against swimming.

The POS areas around the lake will provide space for a range of active and passive recreational activities including walking, picnicking, bird watching, kick-about football and soccer. It is envisaged that facilities within or near the POS will include picnic tables and chairs, barbecues, shade structures and cafés.

2.2.3 Irrigation

Irrigation water for the whole of Austin Cove Stages 1 and 2 as well as other areas including the South Yunderup Sports Club oval will be drawn from the feature lake and the irrigation lake. During early summer, when the salinity of the feature lake is below the bore water salinity of 1,600mg/L TDS, water from this lake will be blended with the bore water used for irrigation. In this way, the overall salinity of the irrigation water will be reduced. Later in summer when the feature lake salinity rises above 1,600mg/L, irrigation water will be drawn entirely from the dedicated 2ha irrigation lake, which will be refilled from the bore.

On average, about 118 megalitres (ML) of water will be drawn from the feature lake each year for irrigation. Most of this will be replaced by bore water. Initially, a maximum of 20 ML will be drawn from the feature lake for irrigation each month. This rate is intended to strike an optimum balance between maximising the use of the low-salinity water, maximising the period for which the lower-salinity water is available, and limiting water level and salinity fluctuations in the feature lake.

The quantity of water available for irrigation from the feature lake will depend on the preceding winter rainfall and the degree of flushing achieved in the lake; after a particularly wet winter, the feature lake may be able to supply most of the following summer's irrigation water.

The use of the feature lake for irrigation will not significantly reduce the demand on groundwater, because the water extracted from the lake will mostly need to be replaced by groundwater. However, the blending of low-salinity water from the feature lake will decrease the overall salinity of the irrigation water for a large part of summer and will increase the ability of landscape and turf species to tolerate irrigation with marginally-suitable bore water later in summer, thereby enabling the estate to utilise a low-quality groundwater resource.

Calculations based on monthly water balance modelling over a 20-year period indicate that, if water from the lake were not available, an average of about 21.7 ML per year of scheme water (at 250 mg/L TDS) would need to be blended with the bore water in order to maintain the same overall salinity in the irrigation water.

Further details of the water balance of the lake and its use for irrigation are provided in Section 4.1.

2.3 Bathymetry

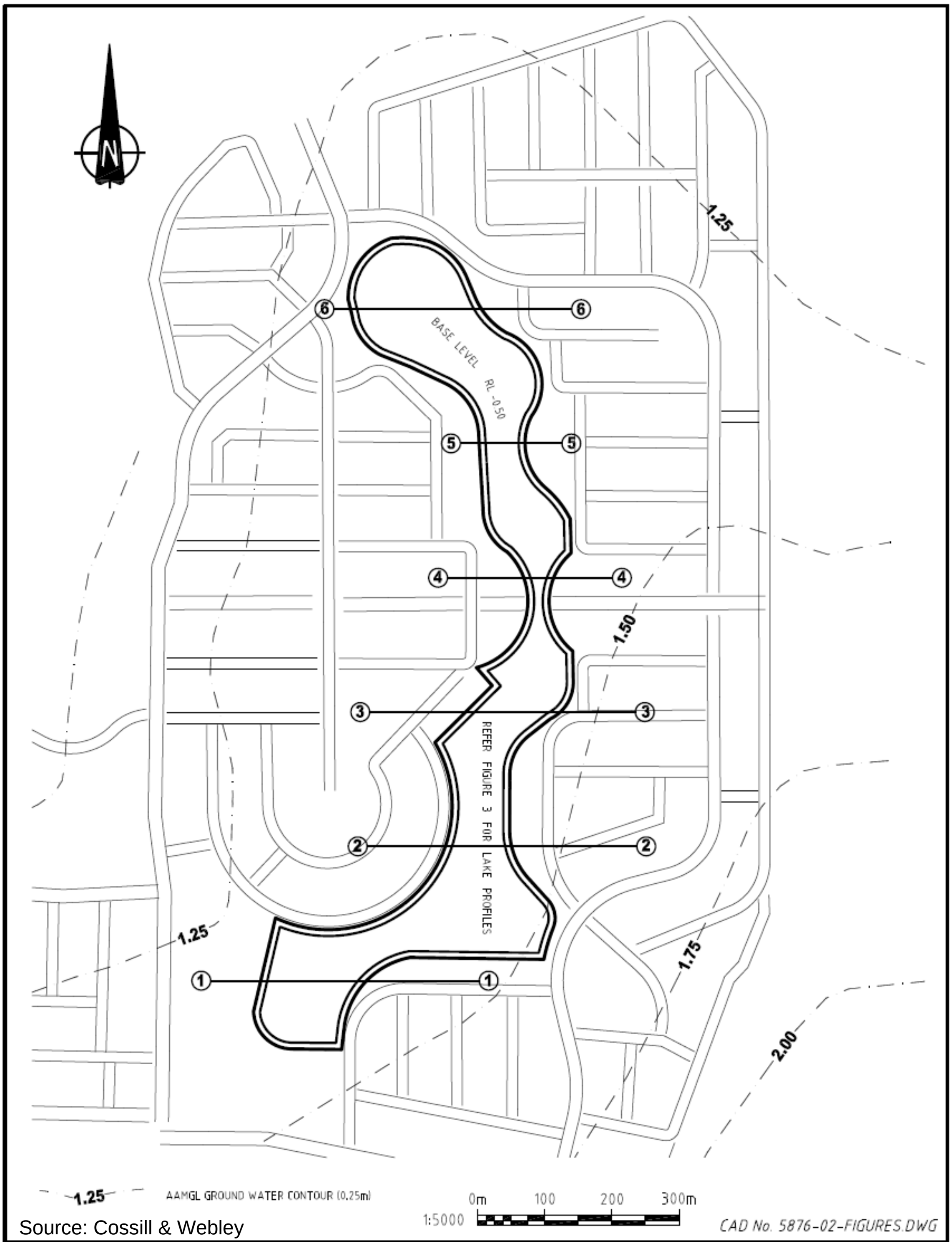
The lake bathymetry and lake floor profiles are shown on Figures 2 and 3 respectively.

The top water level of 2.5m AHD is set nominally 1m below the finished levels of surrounding residential lots, both for aesthetic reasons and to facilitate drainage to lakeside swales. Lot levels are a minimum of 0.5m above the 100-year flood levels determined in the Murray River Flood Study (PWD, 1984).

A base level of -0.5m AHD has been adopted for the feature lake to give a maximum water depth of three metres. This depth has been shown by experience elsewhere to provide adequate wind mixing to avoid stratification while maintaining sufficient depth to avoid wind-induced disturbance of bottom sediments. For instance, the EPA (Bayley *et al.,* 1989) found evidence of large-scale phosphorus release in North Lake, Kardinya, which was approximately 3m deep. More recently, Bowman Bishaw Gorham (2003) found evidence of phosphorus release from sediments in a lake at Bridgewater North, Mandurah, apparently caused by wind-induced disturbance of the sediments in the 1m to 1.5m deep lake. The suitability of the proposed depth has been supported by hydrodynamic modelling of mixing and circulation, as described in Section 3.0.

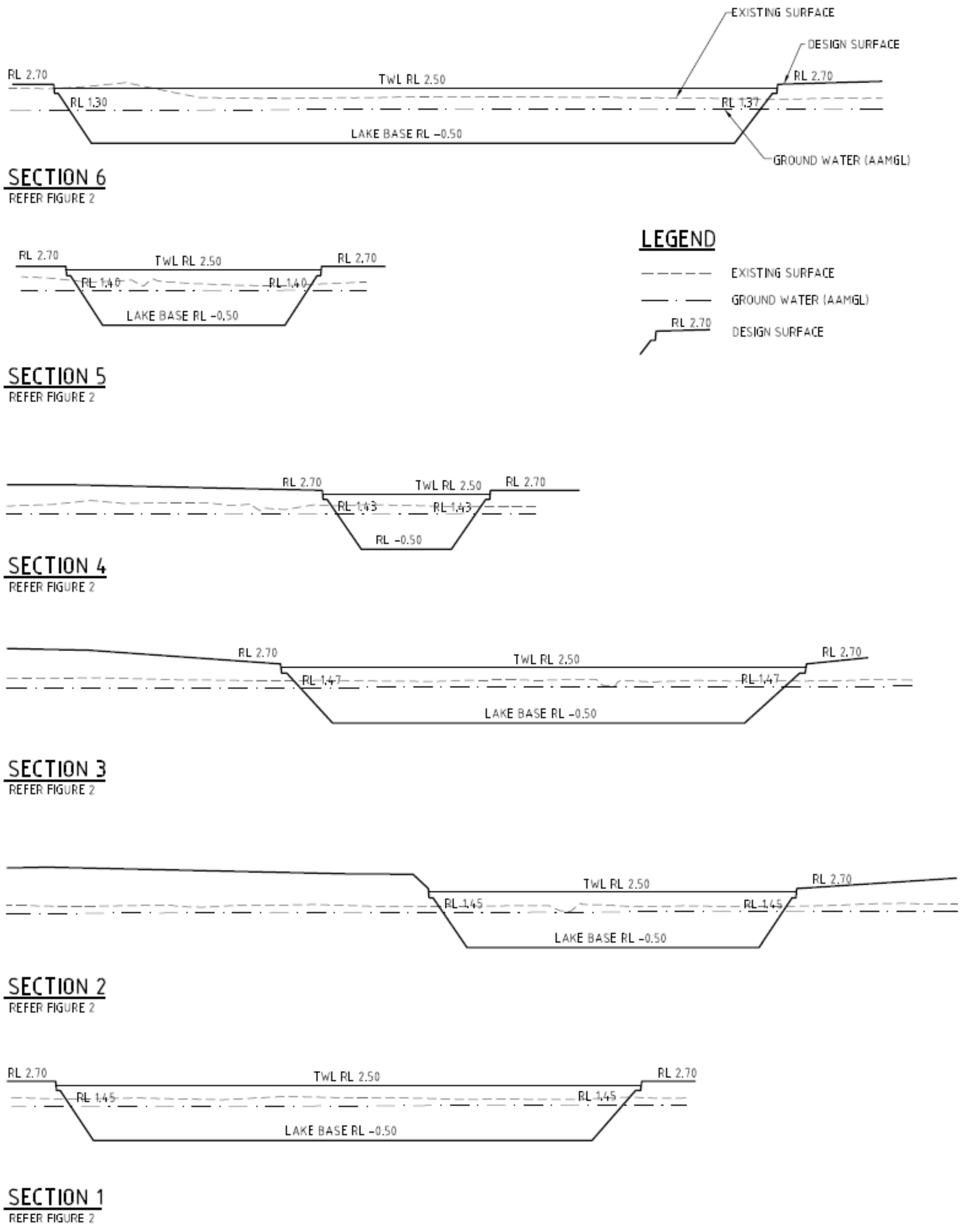
The lake edge profile will consist of one or two 1m wide, 0.3m deep benches, beyond which the lake floor will slope downwards at 1:3.5 to the maximum depth. The shallow bench will serve a safety function by providing a shallow landing for anyone accidentally falling into the lake, as well as a water quality function by minimising areas of very shallow water where high temperatures could encourage growth of insects and algae.

Where reed beds are planted, they will be established on the benched area. Beach areas will be established above the water line. Any watercraft used on the lake such as canoes, sculls etc, can be launched from designated launching facilities such as pontoons or jetties. This measure is intended to minimise the potential for accidental damage to the lake liner.



Source: Cossill & Webley

Figure 2 Lake Bathymetry



Source: Cossill & Webley

CAD No. 5876-02-FIGURES.DWG

Figure 3 Lake Floor Profiles

2.4 Construction

2.4.1 Construction Method

Preliminary Geotechnical Investigations undertaken by Golder Associates (2005) show that excavation for the lake will be in three soil types, these being loose to medium-dense sand, medium-dense clayey sand and stiff to hard sandy clay. The base of the excavation will be predominantly in the last of the abovementioned materials.

Excavated material will be used to fill development areas and thus reduce the amount of imported fill required. Excavation will comply with the provisions of the Acid Sulphate Soil and Dewatering Management Plan to be prepared for the construction works. Water produced from dewatering will be returned to the ground (following treatment to neutralise acidity, if required) around the perimeter of the lake through the surficial sands to avoid any impact on surrounding wetlands.

2.4.2 Lake Liner

The lake will be lined with an synthetic PVC membrane with high tensile, tearing and puncture resistance properties. The liner will be underlain by a 200mm sand bed and overlain by a 300mm sand cover for protection. The liner will extend up and over the lake edges to eliminate overtopping and leakage.

PVC can stretch over 200% without losing its mechanical properties. This enables the material to tolerate a large amount of movement or settlement of the base after construction and to cope with surface preparation that is less than ideal.

The material can be joined or repaired by gluing. On large projects such as Austin Cove installation teams join panels by hot air welding, installing up to 20,000m^2 per day.

Approximately 170,000m^2 of liner will be used to line the lake, comprising about 135,000m^2 of smooth liner applied to the lake floor and 35,000m^2 of textured liner laid on the batters. The textured liner will be used on the batters to prevent slippage of the sand cover.

PVC liners of the type proposed for use in the Austin Cove lake have been tested extensively both in the factory and in the field. These tests include thickness, density, tensile strength, tear resistance, puncture resistance, stress crack resistance, carbon black content and dispersion, oxidative induction time, oven aging, UV resistance, welding onsite (non destructive and destructive testing), trial seaming, surface preparation, anchorage, panel placement and final acceptance.

The liner material proposed to be installed at Austin Cove is manufactured in Australia by Nylex and has been utilised in numerous lakes throughout the Perth Metropolitan Area and elsewhere, all of which remain in good working order. PVC can be used for dam liners, pond liners, leach pad liners, residue area liners, tank liners and as a liner for ornamental landscaping. The following projects have used PVC liners in their construction:

- Alcoa Tailings Pond, Wagerup (Completion mid 1980's)
- Alcoa Tailings Pond, Kwinana (Completion mid 1980's)
- Beaumaris Estate, Iluka – City of Joondalup (Completion 1992)
- Subiaco Redevelopment Greenspine, Subiaco – Town of Subiaco (Completion 1997)
- Brighton Estate, Butler – City of Wanneroo (Completion 2001)
- Harvest Lakes, Atwell – City of Cockburn (Completion 2004)

Nylex warrants its Millennium series of reinforced PVC membranes for 20 years regardless of whether it is covered or uncovered and of the materials with which it is in contact. The situation at the feature lake would be regarded as very benign and a lifetime significantly in excess of the warranty period can be expected. Nylex PVC membrane specifications, installation standards, warranty terms and other documentation describing research into synthetic membrane lifetimes are attached in Appendix A.

The PVC liner is not expected to require any routine maintenance other than annual water balance monitoring to confirm its integrity.

In the event that a leak in the lake liner occurs (as revealed by an excess of inflows over outflows), locating the damage can be achieved using an electrostatic probe and meter which measures changes in water pressure. This can be done simply by walking around the perimeter of the lake and inserting the probe at 20m intervals. Locating holes can also be accomplished through simple visual inspection to the upper margins of the lake where damage typically occurs.

Typically any damage to the liner occurs as small holes (2-5cm) and these are generally self-sealing, resulting in very limited leakage. If repair is required, this can normally be carried out *in situ* without the need to drain or dry the area under repair.

2.4.3 Lake Underdrain System

As the lake floor is partially below groundwater level, it will be necessary to install an underdrain (subsoil dewatering) system underneath the lake to facilitate installation of the lake liner and in case of the unlikely event that the lake needs to be emptied. The underdrain system will consist of a network of subsoil drains connected to a number of sumps into which transportable dewatering pumps can be placed. A conceptual layout of the system is shown on Figure 4.

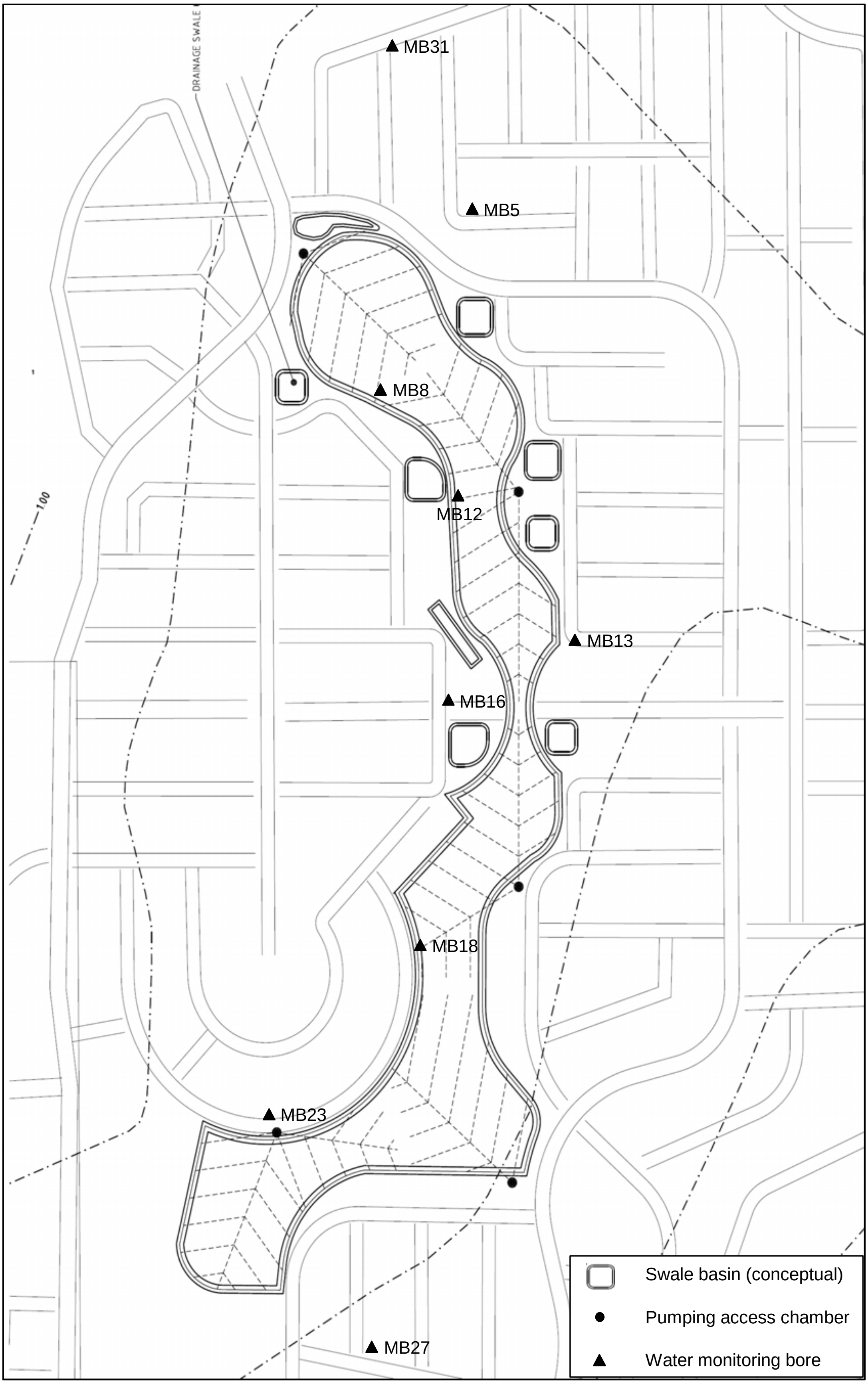


Figure 4 Conceptual Lake Underdrain System

Soil and groundwater testing carried out during the design of the Austin Cove project has found that the groundwater beneath and in the vicinity of the lake has generally low acidity and is unlikely to require treatment before discharge. Detailed data regarding soil and groundwater acidity near the lake are contained in the *Detailed Site Assessment for Acid Sulfate Soils* (RPS BBG, 2007a) and the *Urban Water Management Strategy* (BES and JDA, 2007). Both of these reports have previously been supplied to the DoW.

The data collected to date show that the shallow groundwater near the lake is largely of low acidity. Bores established along the length of the lake site from MB5 in the north to MB27 in the south (Figure 4), which are located on shallow sands overlying Guildford formation clays, have generally shown that the groundwater has:

- pH greater than 6,
- total acidity less than total alkalinity, and
- total acidity less than 40mg/L,

all or which are indicative of non-acidic conditions.

The area north of the lake from MB5 to MB31 (Figure 4), where the soils have a deeper sand profile, shows more acidity, with pH at MB31 seasonally dropping as low as pH 4.0 and total acidity up to about 225mg/L.

The data suggest that the majority of water abstracted from beneath the lake would be strongly buffered and have pH>6, and hence under DEC standards would not require treatment. This water, though not pH affected, may still be treated (by lime dosing, aeration and settling) to precipitate dissolved iron and aluminium prior to onsite recharge or discharge. Dewatering around the northern portion of the lake may draw in more acidic groundwater which would require liming under the established DEC triggers of pH<6 and total acidity >40mg/L. A monitor bore network will be retained around the lake post-construction that would allow for observation and monitoring of any future dewatering against agreed performance targets.

Any proposal to dewater beneath the lake will require licensing by the DoW, at which time further testing and, if necessary, treatment will be carried out.

Depending upon the groundwater quality beneath the lake at the time dewatering was proposed, a number of options would be available for treatment (if necessary), containment and disposal of the produced water. These include:

- Pumping the water from the sumps directly into the lake, where it would be diluted and then discharged to the multiple-use corridor along with the lake water.

- Pumping the water from the sumps into the drainage swales within the lake catchment, from where it would partly recharge back into the dewatering zone beneath the lake to minimise the extent of the cone of depression. Any excess water beyond the capacity of these swales would either overflow into the lake and be discharged as above or be pumped to other swales outside the lake catchment.

- Pumping the water from the swales via overland pipes into a temporary bunded enclosure within the multiple-use corridor, from where it would overflow into the corridor.

The final choice of which option was implemented would be determined in consultation between the developer, the Shire of Murray and/or the Department of Water.

In each of these options, any treatment required for acidity would be undertaken at the point of initial dewatering, and any necessary holding time would be provided by the initial containment (lake, swales or temporary bunded enclosure).

Water produced from the dewatering sumps would be monitored in accordance with the DEC's *Dewatering Effluent and Groundwater Monitoring Guidance* (June 2006). A detailed monitoring program based on this or a contemporary equivalent guideline would be prepared in support of an application for an abstraction licence at the time dewatering was proposed.

2.4.4 Staging of Construction

The lake will be constructed in two sections, with the first (6.8ha) section north of the bridge being completed in about year 3 of the project and the second (9.8ha) section south of the bridge following about two years later. The two stages will be separated by a staging bund that will ultimately be removed to create a single water body.

The staging bund will consist of a pre-laid liner with protective concrete overlay. Soil will be placed on the concrete overlay to form a temporary bund to which the stage 1 lake lining and edge treatments can be constructed. Construction of stage 2 of the lake will involve connection of the stage 2 liner with the pre-laid liner within the staging bund, and removal of the temporary staging bund down to the protective concrete overlay.

Excavation for each stage of the lake is estimated to take approximately 6 to 8 weeks. A further 12 to 14 weeks will be needed to install the bedding, liner and protective cover material. Filling of the lake will commence immediately following placement of the cover material to minimise the time required for dewatering. Construction of lake edge treatments will commence simultaneously with filling of the lake and will take approximately 20 to 26 weeks. Excavation, bedding and lining of the lake would ideally be carried in the summer months to help keep the works area dry.

2.5 Water Sources

2.5.1 Feature Lake

The feature lake will be maintained at a constant water level by means of a combination of pumped Leederville groundwater, roof runoff and direct rainfall. Groundwater will be the primary water source in summer, with up to 1,270m^3/day being required in mid-summer to replace evaporative losses from the lake.

Exploratory drilling and test pumping undertaken in 2006 by Rockwater Pty Ltd demonstrated the availability of groundwater with a salinity of about 1,600mg/L TDS from the Leederville aquifer at a depth of 45-81m. The test results indicated that continuous abstraction at up to 2,160m^3/day could be sustained without excessive drawdown. This water is of marginal quality for irrigation, being suitable for salt-tolerant native landscaping species and some turf types. It is not suitable for irrigation of crops or pasture, and as a result is currently little used in the area. As an artesian aquifer, it does not support any groundwater-dependent ecosystems.

In winter, direct rainfall onto the lake plus roof runoff harvested from about 17ha of roofs will maintain lake levels and create periodic overflows into the multiple-use corridor. The annual water inputs to the lake will comprise about 141,000m^3 of direct rainfall, 125,000m^3 of roof runoff and 173,000m^3 of bore water.

The input of roof water to the lake is important to assist in flushing accumulated salts from the lake during winter, thereby avoiding the need to create artificial turnover during summer by excess input of bore water. This flushing of the lake will also enable low-salinity water from the main lake to be used for irrigation in the early part of summer, improving the capability of the lawns and gardens within the estate to cope with irrigation with marginal groundwater (1,600mg/L TDS) in the latter part of summer.

In order to protect the water quality of the lake, no storm runoff from roads or other surfaces (other than roofs) will be permitted to enter the lake under normal conditions. Although the lake will be a part of the drainage system, only overflow runoff from storm events greater than 5-year ARI will enter the lake.

2.5.2 Irrigation Lake

The 2ha dedicated irrigation lake will be maintained directly by groundwater at 1,600mg/L TDS from the primary bore. This lake will supply water to the irrigation system when the salinity of the main lake is above 1,600mg/L. No stormwater or roof runoff will enter the irrigation lake, although direct rainfall on the lake surface will provide a minor addition to the water balance.

2.5.3 Water Supply Bores and Pumps

Bore pumps will be used to supply top-up water to the feature lake and to the irrigation system via the irrigation lake. The lake top-up pump will be controlled by an automatic water level sensor in the feature lake, and will turn on when the water level drops below 2.3m AHD. The pump will initially operate continuously for about eight months to fill the lake and will thereafter have an operational duty cycle of about 11 hours per day at peak summer demand, dropping to zero in winter.

An auxiliary booster pump station will draw water from the irrigation lake and deliver it to the irrigation distribution system. The pumping station will consist of multiple submersible pumps installed within a wet well and connected to the lake via an outlet structure and screen installed during lake construction.

Two 75L/s pumping stations will be constructed in a modular format to supply the total irrigation requirement of 150L/s. Additional pumps will be installed as the demand on the pump station increases over time until completion of the project.

2.6 Edge Treatments

The lake edge will be designed as a series of smooth, even curves to prevent the collection of rubbish at any one point due to prevailing winds or water stagnation.

Given the range of landscape responses proposed adjacent the lake, a range of different direct lake edges will be required, including walls, turf, planting beds, boardwalks and promenades. These edge treatments are shown on Figure 5 and briefly described below.

Lake Edge Walls
Reconstituted limestone block or similar wall materials typically between 300 – 500mm high will be used to anchor the liner in place, whilst providing a slightly elevated interface with the water body. Typically reconstituted limestone capping or similar capping products will be used to finish the lake walls, with grassed, planted or paved edges behind.

Example Lake Edge Walls

Turf with Concrete Sprayed Edge

Where turf areas are to directly front the lake, a sprayed concrete edge will be used to hold the liner in place, whilst forming a suitably strong mowing edge for ease of maintenance between the water body and turf areas. The sprayed concrete edge will finish typically between 100mm and 200mm above the proposed static water level of the lake, but flush with the adjoining turf areas.


Example Turf Lake Edges.

Planting Bed Edges

Where planting beds are to directly front the lake, two lake edge treatments are typically utilised.

Firstly, where an elevated wall edge is provided to hold the liner in place, planting beds can be catered for adjacent by providing a flat bench of approx 300mm deep water and 1m wide. This provides adequate depth for aquatic plant growth, whilst providing safe access to and from the lake should unauthorised access occur. The extent of aquatic plant growth is controlled by a limestone block below the water line.

Secondly, a formed concrete edge or reconstituted limestone block will be used to hold the liner in place, whilst forming a suitably strong mowing edge for ease of maintenance between the planting areas and the turf areas adjacent. The formed concrete or limestone block edge will finish flush with the surrounding turf and planting areas. Reeds and small water tolerant plant species are able to be planted into the 300mm clean sand fill layer over the liner in the shallower areas of the lake. This is important in providing habitat to the lake edge for fauna, hide fluctuations in water level and limit direct access to the water body.


Example Planting Bed Edges

Boardwalk Edge

Two types of boardwalk edge treatment are planned to be implemented at key focal points, such as around the proposed Village Centre to allow for Al fresco dining opportunities.

Firstly, a cantilevered boardwalk arrangement will be provided in areas where access is required over shallow water areas. The advantage of the cantilevered boardwalk is that it minimises construction issues in regards to penetrations for support posts through the liner. Boardwalk areas with lake water depths greater 300mm will have handrails.

Secondly, a protruding boardwalk will be provided where access over deeper water is required. This lake edge treatment will require penetrations through the liner for support posts and concrete footings with a specialised boot detail to ensure the liner is fully sealed to prevent leaking. As this treatment will have water depths greater than 300mm and a possible fall zone greater than 300mm, a handrail and balustrade will be provided in accordance with the relevant Australian Standards and Building Code of Australia guidelines.

Example Boardwalk Edges

Promenade Edge

A promenade edge is a limestone retaining wall greater than 1m in height from the water surface which will provide direct frontage onto the water body, typically with a hard paving surface behind it. The limestone retaining wall will act as the anchor for the lake liner. As the potential fall is into water deeper than 300mm a limestone / stone pier or similar will be provided, with handrails and balustrades in accordance with the relevant Australian Standards and Building Code of Australia guidelines.

Example Promenade Edges

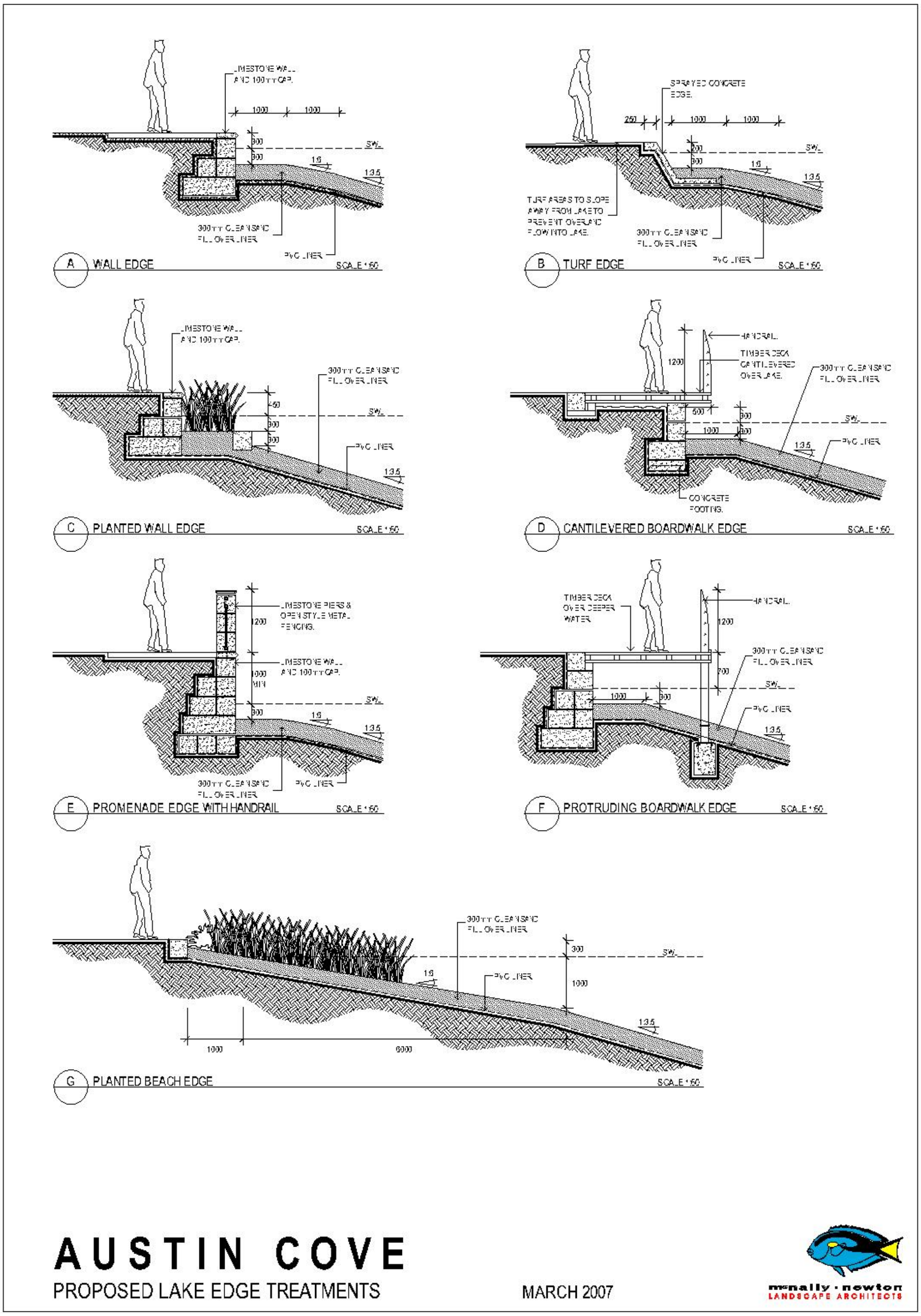


Figure 5 Lake Edge Treatments

2.7 Public Safety

There are no Australian Standards or building regulations governing the installation of handrails and balustrades around open water bodies in public areas within Australia.

Only one fatality has ever been recorded in Western Australia due to accidental drowning in a constructed open water body in an urban area. In response to that fatality, the West Australian Local Government Association has commented that it would be unreasonable to expect fencing to be provided around all open water bodies within the urban environment. Personal responsibility and adult supervision reasonably apply in circumstances involving juveniles and water of any description.

Legislation and regulations governing barriers and balustrades are typically designed to govern responses in built form / buildings only. They are not intended to prevent occupants from entering into or falling from a building portion or level. The only current legislation or standards that are remotely appropriate to fencing or balustrading of water bodies are:

1. Building Code of Australia 1996, vol 1 (BCA)
2. AS 1926.1 - Fencing for Swimming Pools
3. AS 1657 – Fixed Platforms, Walkways, Stairways and Ladders - Design, Construction and Installation.

The BCA legislation is intended to minimise the risk of persons falling, as described in section D2.16 of the Guide. The BCA accepts that balustrades with horizontal foothold or handhold components provide reasonable and adequate levels of safety where a person or child can fall from a heights of 1m up to 4m. The BCA has generally been used as the design benchmark for balustrades inside and outside of buildings. The BCA does not provide any comments or additional requirements where the fall hazard is over water.

AS1926 is only intended to “delay” the entry of children under 5 into private swimming pool enclosures.

AS 1657 is intended to govern “safe access to and safe working at places used by operating, inspection, maintenance and servicing personnel”. AS 1657 specifically states that “this standard does not apply to situations where special provision is made in appropriate building or other regulations”. Based on this statement, the BCA has been regarded as the more appropriate standard to apply in a landscape setting where fall heights are of concern.

As no legislation exists to govern the installation of balustrades or fencing of open water bodies, it is important to assess the risk in association with other design examples within the Perth Metropolitan Area. Such examples include:

1. Numerous man-made water bodies within Shire of Murray, e.g. Ravenswood.

2. Numerous jetties and river banks along the Murray River.
3. Numerous canal frontage lots within the Mandurah / Peel Inlet region.
4. Fremantle Fishing Boat Harbour & restaurant precinct.
5. E Shed Markets & Fremantle Maritime Museum precinct.
6. Old Swan Brewery development including café & restaurant.
7. Mead's Fish Café, Mosman Park.
8. Red Herring restaurant, North Fremantle.
9. Numerous yacht club facilities on the Swan River.
10. Numerous jetties and river walls on the Swan River.
11. Marina Boardwalk at Hillarys Boat Harbour – including numerous cafes.
12. Mends & Barrack Street Jetties – South Perth & Perth, including cafés, pubs & restaurants.
13. Langley Park wetlands development – City of Perth.

The proposed lake at Austin Cove is part of the broader Public Open Space community facilities and is expected to have a medium level of patronage. The abovementioned facilities are well used by the public and have high levels of patronage. None have balustrades or fencing protecting the water's edge. All have a fall distance and water depth greater than that proposed at Austin Cove.

As per the typical sections provided within the Lake Management Plan, the following measures are currently proposed to contribute to safety of the open water body:

Detail A – Wall Edge

1. An initial shallow bench (-100mm-400mm deep water) adjacent to all lake edges for approx 1m in length. This provides for safe and easy egress from the water body should unauthorised entry occur.
2. A second bench (300mm-800mm deep water) 1m wide adjacent to the first bench. This provides safe egress from the water when lake levels are at their lowest and the first bench is exposed.
3. Consistent gradual depth grade of 1:6 for first 2 metres avoiding local deep areas or drop-offs. Thereafter a 1:3.5 grade will apply which enables best preservation of water quality.
4. Water level maintained within a maximum range of 500mm.
5. Paving materials and colour change between footpath and lake edge capping provides visual definition for visually impaired.
6. Non slip surfaces applied to paved areas adjacent lake to prevent slippage.

Detail B – Turf Edge

1. An initial shallow bench (-100mm-300mm deep water) adjacent to all lake edges for approx 1m in length. This provides for safe and easy egress from the water body should unauthorised entry occur.
2. A second bench (300mm-800mm deep water) 1m wide adjacent to the first bench. This provides safe egress from the water when lake levels are at their lowest and the first bench is exposed.

3. Consistent gradual depth grade (1:6 for first 2 metres to a depth of 500mm) avoiding local deep areas or drop-offs. Thereafter a 1:3.5 grade will apply which enables best preservation of water quality.
4. Water level maintained within a maximum range of 500mm.
5. Grass immediately adjacent to lake edge grades gently away from the lake to prevent runoff from lawn areas into lake.

Detail C – Planted Wall Edge

1. An initial shallow bench (-100mm-300mm deep water) adjacent to all lake edges for approx 1m in length. This provides for safe and easy egress from the water body should unauthorised entry occur. Bench is densely planted with sedges and similar species to discourage entry when water level is low.
2. Consistent gradual depth grade of 1:6 for first 2 metres avoiding local deep areas or drop-offs. Thereafter a 1:3.5 grade will apply which enables best preservation of water quality.
3. Water level maintained within a maximum range of 500mm.
4. Paving materials and colour change between footpath and lake edge capping provides visual definition for visually impaired.
5. Non slip surfaces applied to paved areas adjacent lake to prevent slippage.

Detail D – Cantilevered Boardwalk Edge

1. An initial shallow bench (-100mm-300mm deep water) adjacent to all lake edges for approx 1m in length. This provides for safe and easy egress from the water body should unauthorised entry occur.
2. Consistent gradual depth grade of 1:6 for first 2 metres avoiding local deep areas or drop-offs. Thereafter a 1:3.5 grade will apply which enables best preservation of water quality.
3. Water level maintained within a maximum range of 500mm.
4. Approved balustrades/handrails will be provided to structures such as boardwalks which overhang the lake and areas of deeper water to minimise the potential for falling.

Detail E – Promenade Edge with Handrail

1. An initial shallow bench (-100mm-300mm deep water) adjacent to all lake edges for approx 1m in length. This provides for safe and easy egress from the water body should unauthorised entry occur.
2. Consistent gradual depth grade of 1:6 for first 2 metres avoiding local deep areas or drop-offs. Thereafter a 1:3.5 grade will apply which enables best preservation of water quality.
3. Water level maintained within a maximum range of 500mm.
4. Approved balustrades/handrails will be provided to structures such as boardwalks which overhang the lake and areas of deeper water to minimise the potential for falling.

Detail F – Protruding Boardwalk Edge

1. An initial shallow bench (-100mm-300mm deep water) adjacent to all lake edges for approx 1m in length. This provides for safe and easy egress from the water body should unauthorised entry occur.
2. Consistent gradual depth grade of 1:6 for first 2 metres avoiding local deep areas or drop-offs. Thereafter a 1:3.5 grade will apply which enables best preservation of water quality.
3. Water level maintained within a maximum range of 500mm.
4. Approved balustrades/handrails will be provided to structures such as boardwalks which overhang the lake and areas of deeper water to minimise the potential for falling.

Detail G – Planted Beach Edge

1. Consistent gradual depth grade of 1:6 for first 2 metres from the water's edge avoiding local deep areas or drop-offs. Thereafter a 1:3.5 grade will apply which enables best preservation of water quality.
2. Water level maintained within a maximum range of 500mm.
3. Planting buffers in some areas will restrict or discourage direct access to the water's edge.
4. Grass immediately adjacent to lake edge grades gently away from the lake to prevent runoff from lawn areas into lake.

General Principles

1. Signage advising against swimming and diving will be placed at intervals around the lake, with wording and locations in accordance with relevant Australian Standards.
2. Water level changes will be kept to less than 500mm so that safety features are not compromised.

2.8 Public Facilities

The open water body will be fringed with parkland areas that offer a range of recreation and community facilities. These parkland areas will serve both as informal active and passive recreation functions. The parkland adjoining the lake will consist of open grassed spaces bounded and defined by both feature avenue trees and native tree clumps. Shrub plantings are planned to strategic areas to provide spatial definition and colour where required. Shrub planting will primarily consist of lower growing species to enable clear vision and security through passive surveillance. It is proposed that the shrub plantings will consist primarily of native species, with some exotic species in key locations. All shrub plantings will have a consideration and adherence to Waterwise principles and maintenance minimisation.

The incorporation of landscaped areas fronting the water body and its associated facilities will provide a setting for picnics and informal gatherings. Barbecues and picnic shelters within smaller open areas suitable for informal active recreation will exist.

These open areas will vary in size from 20m to 80m diameter. Vista views and formal path systems to the parkland areas will connect each smaller space generally. All spaces are intended to have water views.

The Central Open Space will incorporate dual use and pedestrian path systems with built-in vehicular crossing and access points for maintenance purposes. Dual use and pedestrian systems will provide smooth and easy access to all features of the open space and link into residential and other areas adjacent. Disability access will be given a high priority and will be designed in accordance with relevant Australian Standards.

3.0 LAKE HYDROLOGY MANAGEMENT

3.1 Inflows and Outflows

The feature lake will receive water inputs from direct rainfall, roof runoff (from a 17ha catchment), groundwater (via the bore) and, occasionally (less than once every five years on average), stormwater runoff. The lake will lose water to evaporation, overflow (mostly in winter) and irrigation (in summer). The magnitude of each of these inputs and outputs will depend primarily on rainfall; in wet years, inputs from rainfall and roof runoff will be high, while low salinity might mean that the lake is almost the sole source of irrigation water. In dry years, bore water will be the main input while output for irrigation will be reduced due to the higher salinity.

Overflow from the lake will occur regularly in winter during significant storm events. Outflow will exit the lake via an overflow weir or similar structure at the south-west corner of the lake. The overflowing water will travel by open channel or underground pipe into the multiple-use corridor, flowing west through a series of streams, reed beds, ponds and other features designed to slow and further purify the water before it discharges into the floodway at the south-west corner of the project area. The lake overflows will make up a minor and intermittent component of the flow in the multiple-use corridor.

3.2 Water Level Regulation

The feature lake will be maintained at a nominal water level of 2.5m AHD by means of a combination of pumped Leederville groundwater, roof runoff and direct rainfall. Details of the water sources used to maintain the water level were given in Section 2.5.

The lake level will vary by up to 0.2m above or below the nominal level. In summer, the bore pumps will automatically start when the lake level drops below 2.3m AHD, while in winter, the lake will overflow to the multiple-use corridor when rainfall, roof runoff and occasional stormwater overflow raise the lake level above 2.7m. The turning-on of the pumps at low water level will be controlled by an automatic level switch. The overflow level will be controlled by a fixed overflow weir or similar at the south-west corner of the lake.

At the end of autumn, the lake will be allowed to fall to 2.2m in order to maximise the storage capacity for winter rainfall.

The difference between the top and bottom water levels represents a volume of 78ML over the area of the lake. In operation, the lake will be managed so that the input of bore water is minimised and the availability of water for irrigation is maximised. This will include the following:

- In summer, the lake level will be maintained at 2.3m AHD rather than the nominal 2.5m full level. This will reduce the demand for top-up water.

- At the end of summer, the lake level will be allowed to fall to approximately 2.2m AHD in order to maximise the capacity to capture early winter rainfall and roof runoff.

- At the end of winter, the lake level will be at or close to 2.7m AHD when irrigation commences. Bore inflow will not commence until the lake level is drawn down to below 2.3m AHD.

The water level of the irrigation lake will vary throughout the day in summer as water is removed for irrigation (mostly at night) and replenished by the bore pumps. In winter, excess water, if any, from rainfall on the irrigation lake will overflow into the main lake.

3.3 Water Balance

Water balance modelling of the feature lake was conducted for a 20 year period from initial construction, incorporating the expected two-stage lake construction and development of roads and roof areas (JDA, 2006). The modelling covered the period 1 September 2010 to 31 December 2029 using the proposed project staging and real historical meteorological data from the equivalent dates in 1987 to 2006. This period was one of generally below-average rainfall but contained at least one ten-year storm event (in July 1991, representing July 2014 in the model).

Figure 6 shows a graph of fluctuations in water level over the 20 year period from 2010 (initial lake filling) to 2029. The north lake is effectively filled to 2.3m AHD after four months, with a volume of approximately 110,000m^3. The graph also shows the dip in water level to 0.9m AHD in January 2012, when the south lake is expected to be completed and joined to the north lake. From that time on the water level will be held within the range of 2.3m to 2.5m AHD.

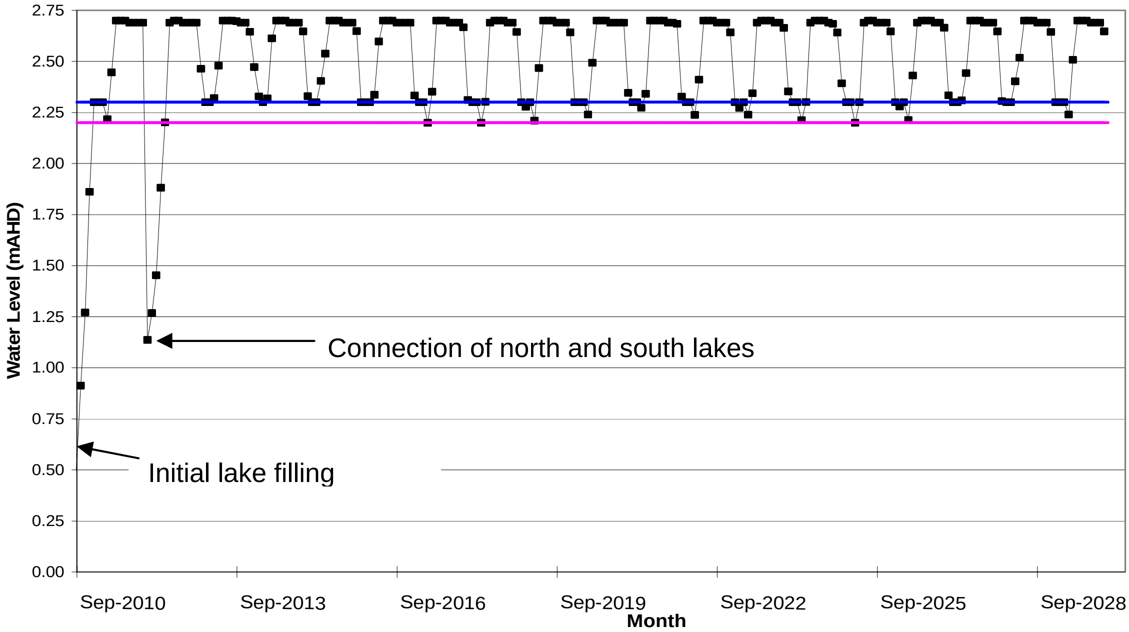
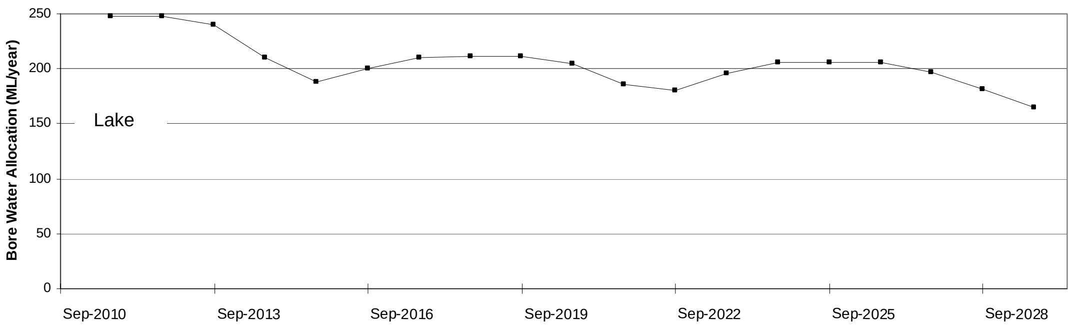


Figure 6 **Predicted Lake Water Level 2010-2029**

Figure 7 shows the 3-year moving average bore water allocations for lake top-up and irrigation, assuming that 118 ML/yr of water is drawn from the feature lake for irrigation.



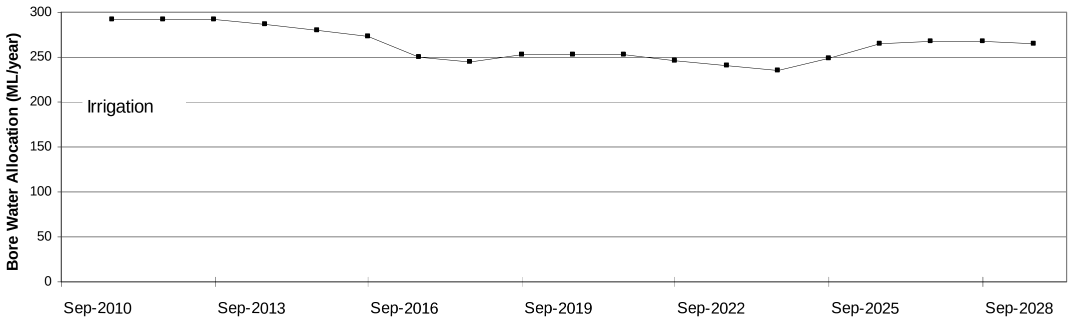


Figure 7 **Predicted 3-year Moving Average Bore Water Consumption for Lake Top-up and Irrigation 2011-2029**

Table 3.1 shows an overall summary of the lake water balance and bore water requirement for the years of the completed lake, 2012 to 2029.

Table 3.1 Annual Water Balance for Main Lake 2012 to 2029[1]

Component (all units in ML/year unless stated otherwise)	**Value**	**% of total**
Rain water input	141	32%
Groundwater input	173	39%
Roof water input	125	28%
Total Inputs	**439**	100%
Evaporation output	-229	52%
Irrigation output (begins about 2011)	-118	27%
Overflow	-93	21%
Total Outputs	**-439**	100%

1 The calculation starts after Stage 1 of the lake development is finished (year 3 of the project) and Stage 2 completed in year 5 of the project.

3.4 Modelling of Different Lake Sizes

Modelling was undertaken to simulate different lake sizes of 20ha, 11ha, 9ha and 2ha. As in the previous model, the lake received winter runoff from a 16.8ha roof catchment, and was used as the preferred source of irrigation water whenever the salinity of the lake was less than that of the bore water.

The area removed from or added to the lake was assumed to be balanced by a change in the area of POS surrounding the lake, which would be planted and irrigated in line with the current conceptual landscape plan for the central POS, which is as follows:

- Turf areas
  - 60% of total POS.
  - Irrigated twice weekly for 35 weeks/year at 15mm per application.
  - Annual water consumption 10,500 kL/ha.

- Native gardens
  - 40% of total POS.
  - Irrigated twice weekly for 35 weeks/year at 5mm per application.
  - Annual water consumption 3,500 kL/ha.

- Annual water consumption for total POS = 7,700 kL/ha.

The lake inflows and outflows for the various lake sizes together with the total groundwater requirement are summarised in Table 3.2 and illustrated on Figure 8.

The results of this modelling can be summarised as follows:

- For the 16.6ha lake, the total annual groundwater requirement for lake top-up and irrigation is 409ML/yr.

- For a 9ha lake the total groundwater requirement for lake recharge and irrigation is 433ML/yr, an increase of 24ML/yr over the 16.6ha lake.

- For an 11ha lake the total groundwater requirement increases further to 435ML/yr.

- For a 2ha lake (irrigation buffer lake only), most of the roof runoff in winter is lost to overflow from the lake. Total groundwater requirement is greater still at 449ML/yr.

- For a 20ha lake a lack of adequate flushing with roof runoff during winter meant that less lake water could be used for irrigation. This resulted in a higher total annual groundwater requirement than the 16.6ha lake, at 429ML/yr.

The overall finding of the modelling is that, of the different lake sizes examined, the 16.6ha lake results in the lowest total bore water requirement of 409ML/yr. The smaller lake sizes and correspondingly greater irrigation areas require a larger total bore water requirement, while the larger 20ha lake is limited by water quality from being used for irrigation.

It is important to note that modelling such as that described above can only provide an approximation of the real situation, and the actual quantities of water will vary depending on many factors including climate and the influence of minor variables that are not adequately accounted for by the model.

The water balance modelling will be progressively refined to optimise the design of the lake and the efficiency with which water is used in the lake and irrigation system. Following the lake's construction, the water balance model will continue to be updated with real data so as to enable the operating regime of the bore pumps and irrigation system to be optimised to save water.

Table 3.2 Water and Salt Balance Modelling of Lake 2012-2029 Average

Description (all units ML/yr unless otherwise stated)	**16.6ha lake Original Model**		**16.6ha lake Refined Model**		**Alternative 1: 11ha lake**		**Alternative 2: 9ha lake**		**Alternative 3: 2ha lake**		**Alternative 4: 20ha lake**	
	Value	**% of total**	**Value**	**% of total**	**Value**	**% of total**	**Value**	**% of total**	**Value**	**% of total**	**Value**	**% of total**
Rain water input	141	31%	141	32%	93	22%	76	19%	17	6%	170	35%
Bore water input	193	42%	173	39%	210	49%	194	49%	126	47%	185	39%
Roof water input	125	27%	125	28%	125	29%	125	32%	125	47%	125	26%
Total Inputs	**459**	100%	**439**	100%	**429**	100%	**395**	100%	**268**	100%	**480**	100%
Evaporation output	-242	53%	-229	52%	-160	37%	-131	33%	-29	11%	-292	61%
Irrigation output	-60	13%	-118	27%	-171	40%	-172	44%	-141	52%	-85	18%
Overflow	-157	34%	-93	21%	-98	23%	-92	23%	-98	37%	-103	22%
Total Outputs	**-459**	100%	**-439**	100%	**-429**	100%	**-395**	100%	**-268**	100%	**-480**	100%
Min lake salinity in 2029 (mg/L)	1256		1261		1069		927		53		1616	
Max lake salinity in 2029 (mg/L)	1903		1925		1830		1706		2217		2294	
Net evaporation (evaporation-rainfall)	-101		-88		-67		-55		-12		-122	
Groundwater requirement for irrigation	**354**		**354**		**396**		**411**		**464**		**329**	
Net groundwater requirement for lake	**133**		**55**		**39**		**22**		**-15**		**100**	
Total groundwater requirement	**487**		**409**		**435**		**433**		**449**		**429**	

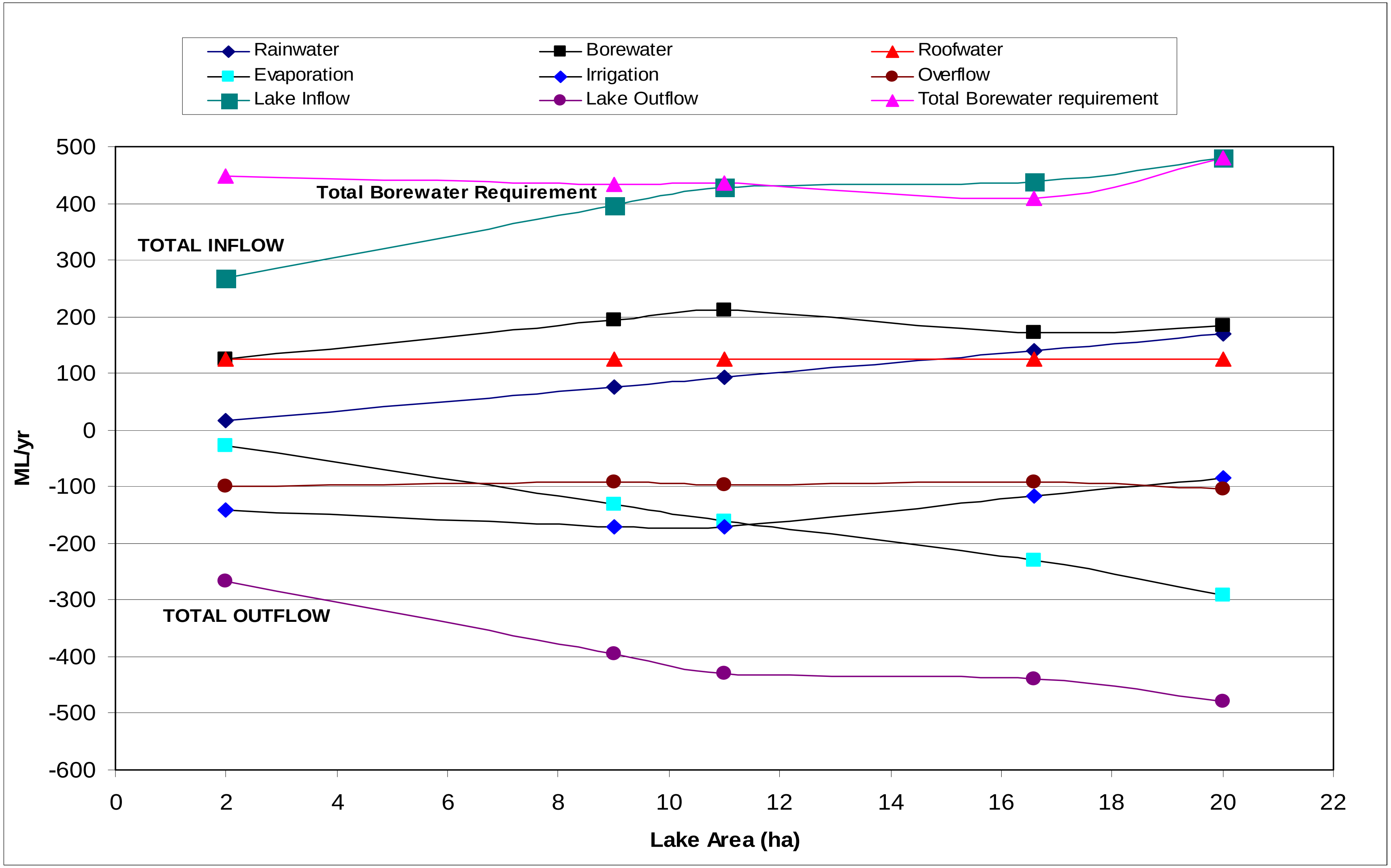


Figure 8 **Lake Water Balance and Total Bore Water Requirement (average 2012-2029)**

3.5 Circulation and Mixing

Satterley Property Group commissioned WorleyParsons to conduct three-dimensional hydrodynamic modelling of the feature lake in order to assess the circulation and vertical mixing within the lake.

It is necessary to assess the vertical and horizontal mixing within the lake as these will influence the rate of vertical and horizontal mass transport of nutrients and algae. Other studies have shown that most algal bloom events happen under prolonged stratification in the spring-summer period where solar radiation and the vertical flux of nutrients from the bottom sediments reach their peak.

The full report of the circulation modelling study is presented in Appendix B and summarised below.

3.5.1 Model Description

The Danish Hydraulics Institute's MIKE 3 model was used for the study. MIKE 3 is regarded as the state of the art for simulating three-dimensional free-surface flows. It is applicable to simulations of hydraulics, water quality and sediment transport in rivers, lakes, estuaries, bays, coastal areas, seas and other water bodies. MIKE 3 simulates unsteady flow taking into account density variations, bathymetry and external forcing such as meteorology, tidal elevations, currents and other hydrographic conditions.

Simulations were completed using real historical meteorological data to represent three seasonal cases:

Summer	1 January 2001 – 2 February 2001
Autumn	2 April 2001 – 4 May 2001
Winter	16 June 2000 – 17 July 2000

Spring conditions are similar to both autumn and summer in part, and therefore the expected response in spring can be extrapolated from the other runs. The model was run for a period of 4 weeks for each of the three seasons. These periods were chosen as representative of typical wind and atmospheric conditions in that season.

The following points summarise the key model parameters:

1. The model was run with a 5 second time-step.

2. The model was a closed system with no open boundaries, reflecting the fact that the lake will be lined and perched with no groundwater inflow or outflow.

3. The model included wind forcing as well as atmospheric forcing and heat exchange to simulate density driven flows. The simulations have been set up

using the best currently available metrological data (combined Perth and Mandurah data sets).

4. Meteorological data for the selected model periods was provided by the Bureau of Meteorology (BOM) for the closest meteorological stations to the site. Air temperature, relative humidity, and rainfall from Mandurah, evaporation from Medina station and cloud cover from Perth Airport were used. Hourly wind data for Mandurah was obtained from the Bureau of Meteorology for the simulation periods. The wind speed and direction, air temperature, relative humidity, clearness (inverse of cloud cover), evaporation and precipitation data for the simulation periods are presented in Appendix B.

5. Inflows to the lake included direct rainfall, roof runoff and bore water inflow (topping up the lake during dry months) as follows:

   - Roof runoff was directed into the lake via 12 inflow points distributed around the lake as shown on Figure 9.
   - The rate of the bore water inflow was assumed to be $0.025m^3/s$. The location of the bore water inflow is shown on Figure 9.
   - Inflow from direct rainfall is accounted for in the atmospheric forcings.

6. Overflow was assumed to occur whenever the lake water level reaches 2.7m AHD. Overflow discharge rate was not limited; i.e. once the water level exceeded 2.7m AHD all water above that level was assumed to be released in the following hour of the simulation. The location of the overflow point is shown on Figure 9.

The initial lake conditions were as follows:

	Winter	**Summer**	**Autumn**
Temperature (˚C)	16.0	23.0	19.0
Salinity (PPT)	2.5	2.5	2.5

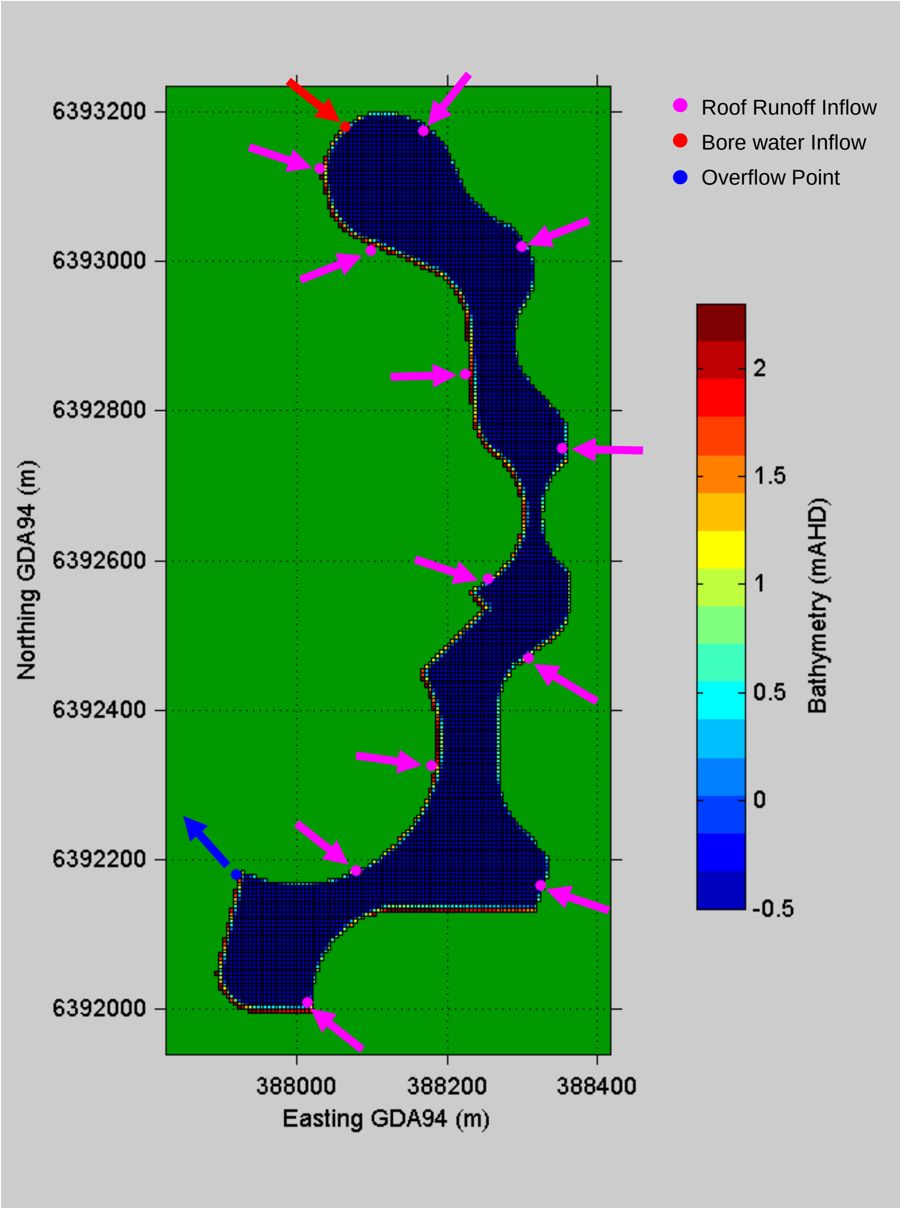


Figure 9 Location of Inflow and Outflow Points Overlain on the Lake Bathymetry

3.5.2 Results

Animations of the current magnitude and direction in the surface and bottom layers for each season have been prepared to assist in the interpretation of the model results. The animations show that there are no zones of poor circulation in the lake. The animations are presented on a companion CD which forms a part of the Hydrodynamic Modelling report (Appendix B).

Circulation and Mixing

Generally, the modelled circulation within the lake is dominated by wind forcing. The predominant winds are south-westerly wind in summer, south-easterly and north-westerly in winter. No predominant wind is predicted during autumn.

Most of the time the surface currents are in the same direction as the wind and their magnitude is proportional to the wind strength. The bottom currents are generally in the opposite direction to the surface currents, indicating circulation, turnover and mixing of the water within the lake. Typical circulation currents in the lake under the influence of wind are shown on Figure 10.

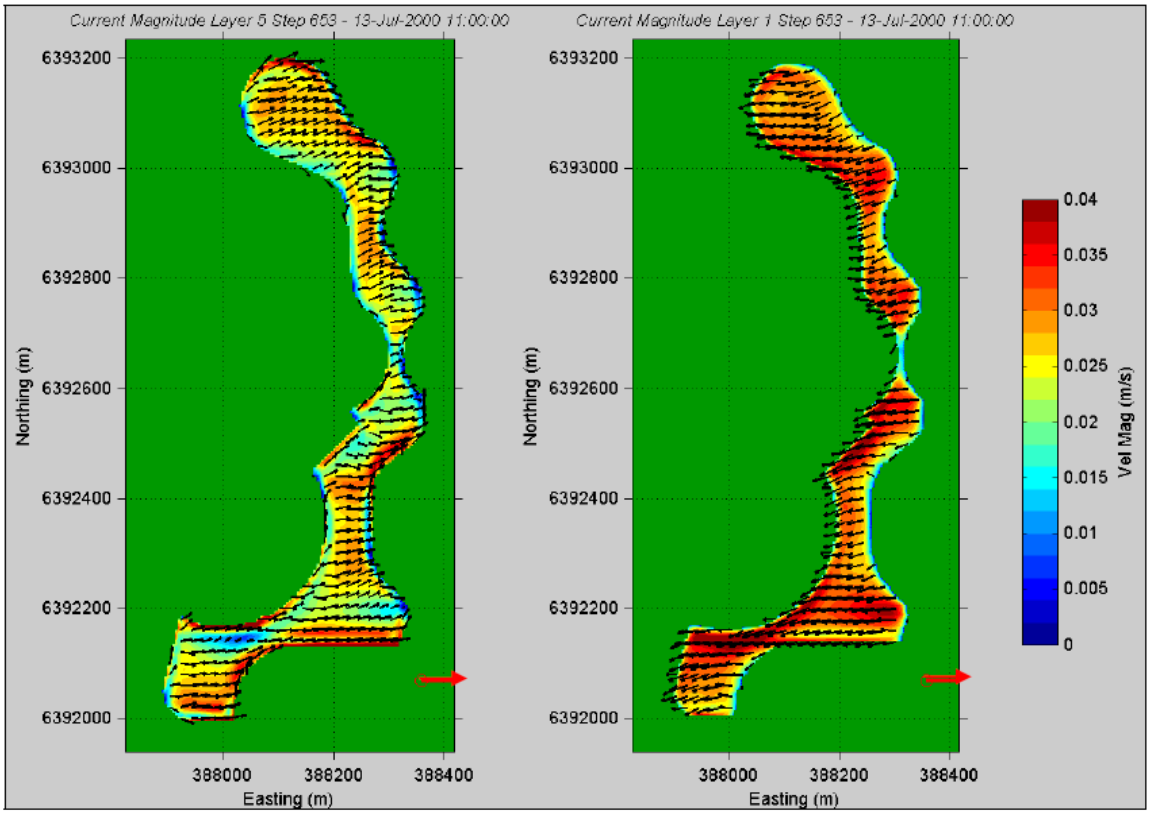


Figure 10 **Typical Surface (left) and Bottom (right) Currents in Winter.**
Red Arrow Indicates Wind Direction.

Density-driven currents, driven mainly by differential heating of the lake, will also influence the circulation but, due to the dominance of the wind, this effect is only apparent during times of low wind. An example of this is shown on Figure 11 when the wind speed is less than 0.5 m/s. A cross-section of the spatial temperature distribution at this time (Figure 12) shows that, despite this low wind, the lake water column will not be stratified.

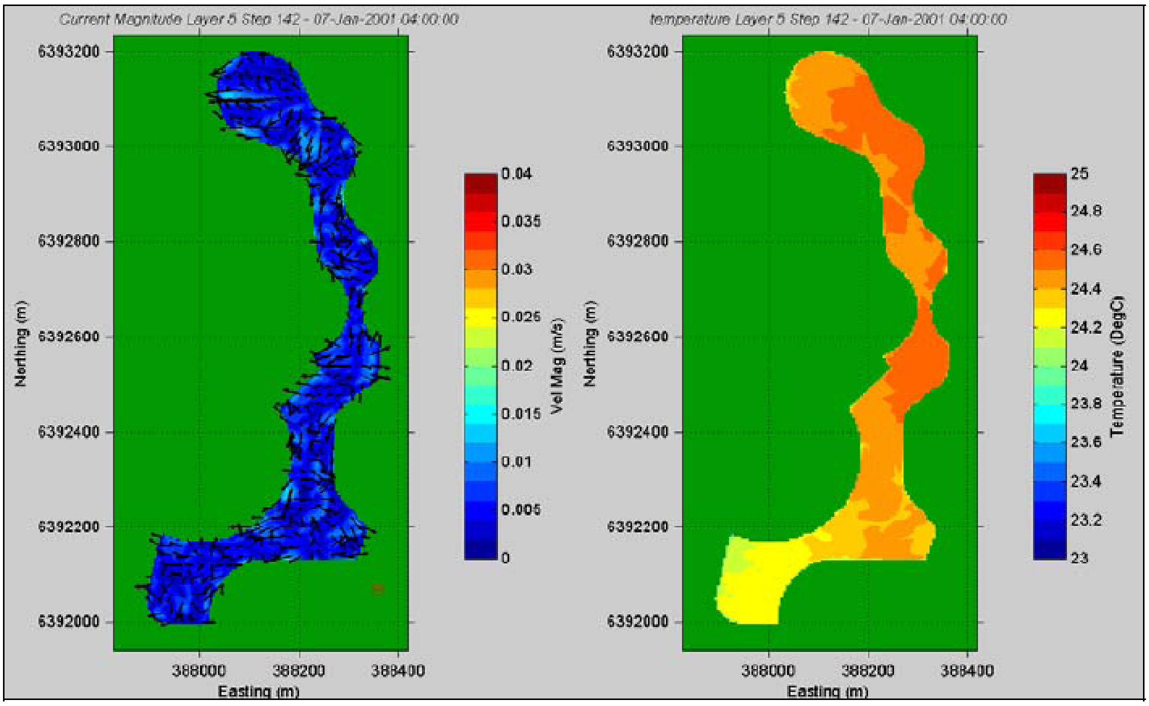


Figure 11 **Velocity Magnitude and Direction (left) and Temperature (right) in the Surface Layer for one day in Summer.**

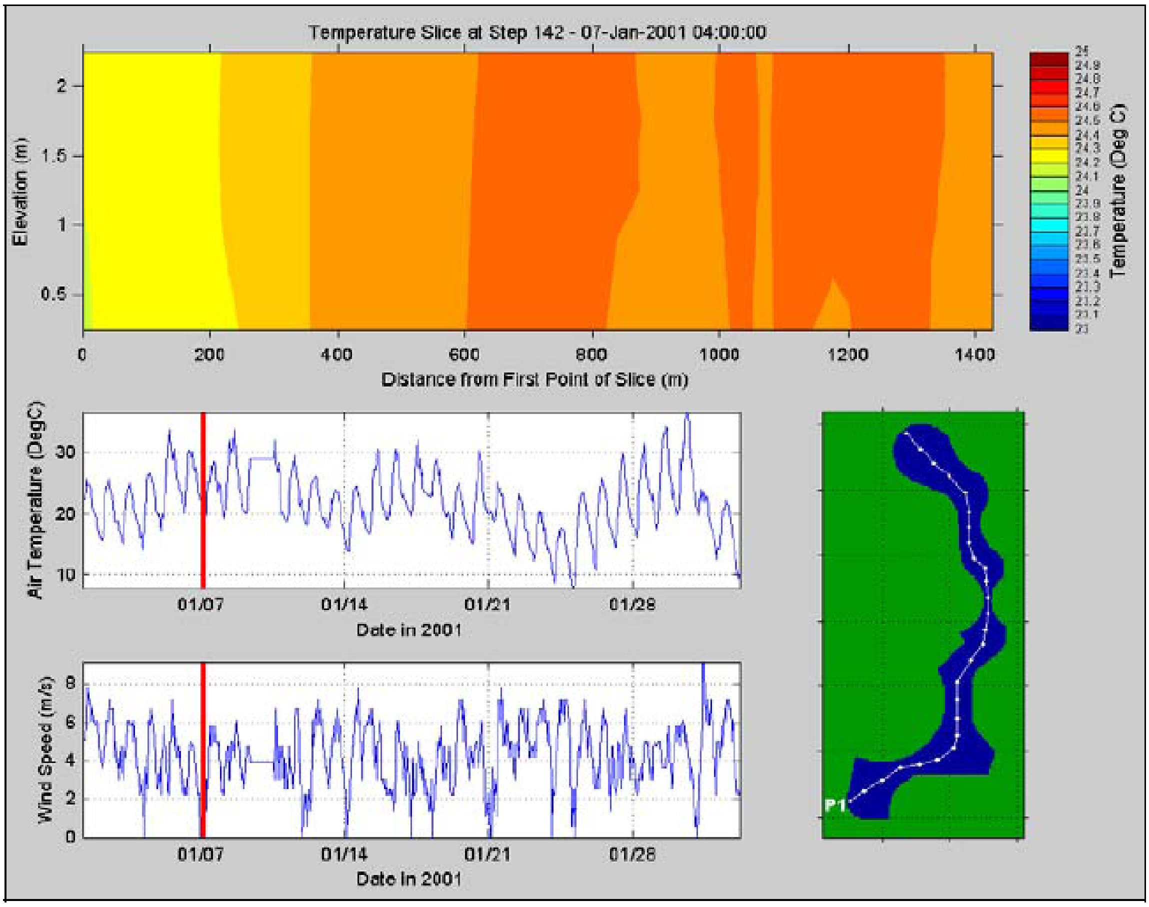


Figure 12 **Temperature Slice Along the Lake (top), Air Temperature (middle) and Wind Speed (bottom) on the Same Day as Figure 11.**

The modelling shows that over the one-month simulation periods the lake does not completely mix over its entire length, although some end-to-end mixing does occur. The model also suggests that the narrowing of the lake in the middle at the road crossing is the reason for the less than perfect circulation. The option is available to optimise the circulation between the two halves of the lake by widening the central constriction, if further modelling indicates that this is warranted.

Comparison over the seasons reveals that the autumn period is predicted to have the least energetic circulation and mixing, which is expected due to the generally lighter winds during this season. However, the mixing in summer (the critical period for water quality) is more efficient due to the stronger winds.

Figure 13 illustrates the degree of mixing between the two halves over a typical month in summer.

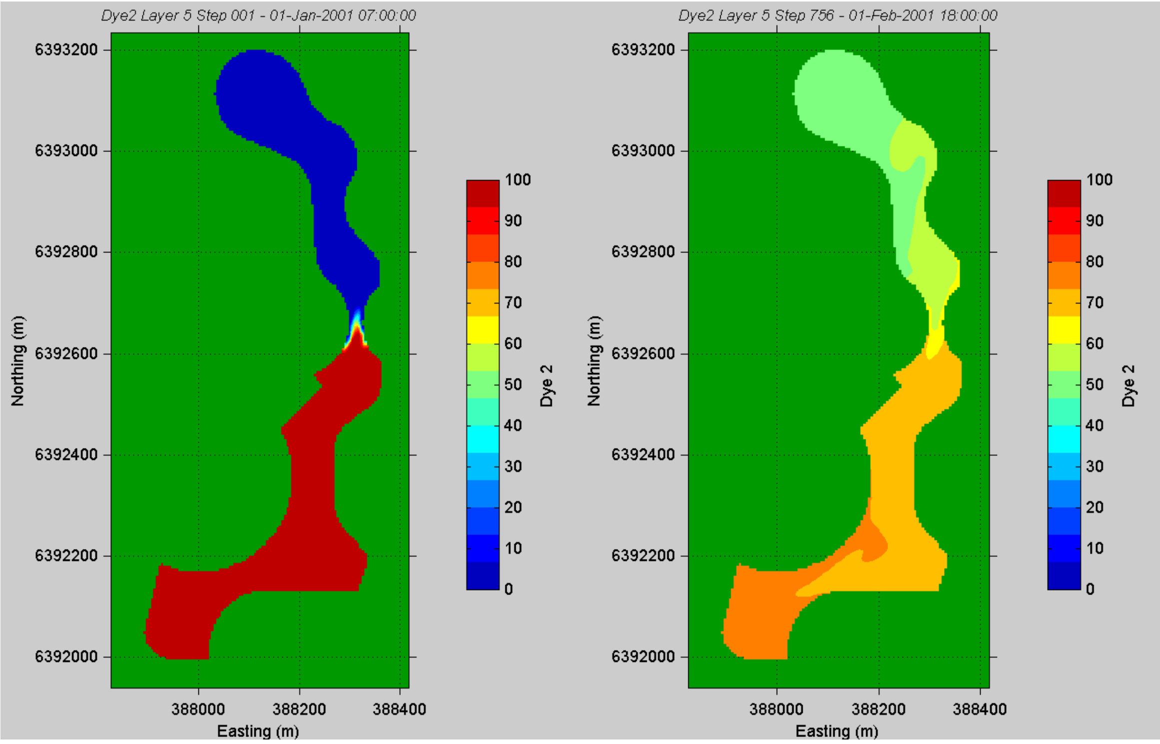


Figure 13 **Initial (left) and Final (right) Mixing (dye tracer concentration) over One Month in Summer**

<u>Density Currents</u>

The spatial variation in temperature and salinity was assessed to predict the influence of density-driven flows on the circulation of the lake, by comparing time-series of temperature and salinity extracted at a range of points within the lake. The results reveal that there are minimal variations in salinity across the lake for all sections.

There are some significant spatial variations in the temperature of the surface and bottom layers across the lake during the autumn and summer simulations. These variations are generally during daylight hours when the surface layer is heated by solar radiation. However, convective cooling during the night will mix the water column, ensuring that any stratification is short-lived. The winter simulation has minimal temperature variation across the lake, indicating that the lake is generally well mixed throughout the winter months. Sample time-series plots of temperature and salinity across the lake for the summer simulation are shown on Figure 14.

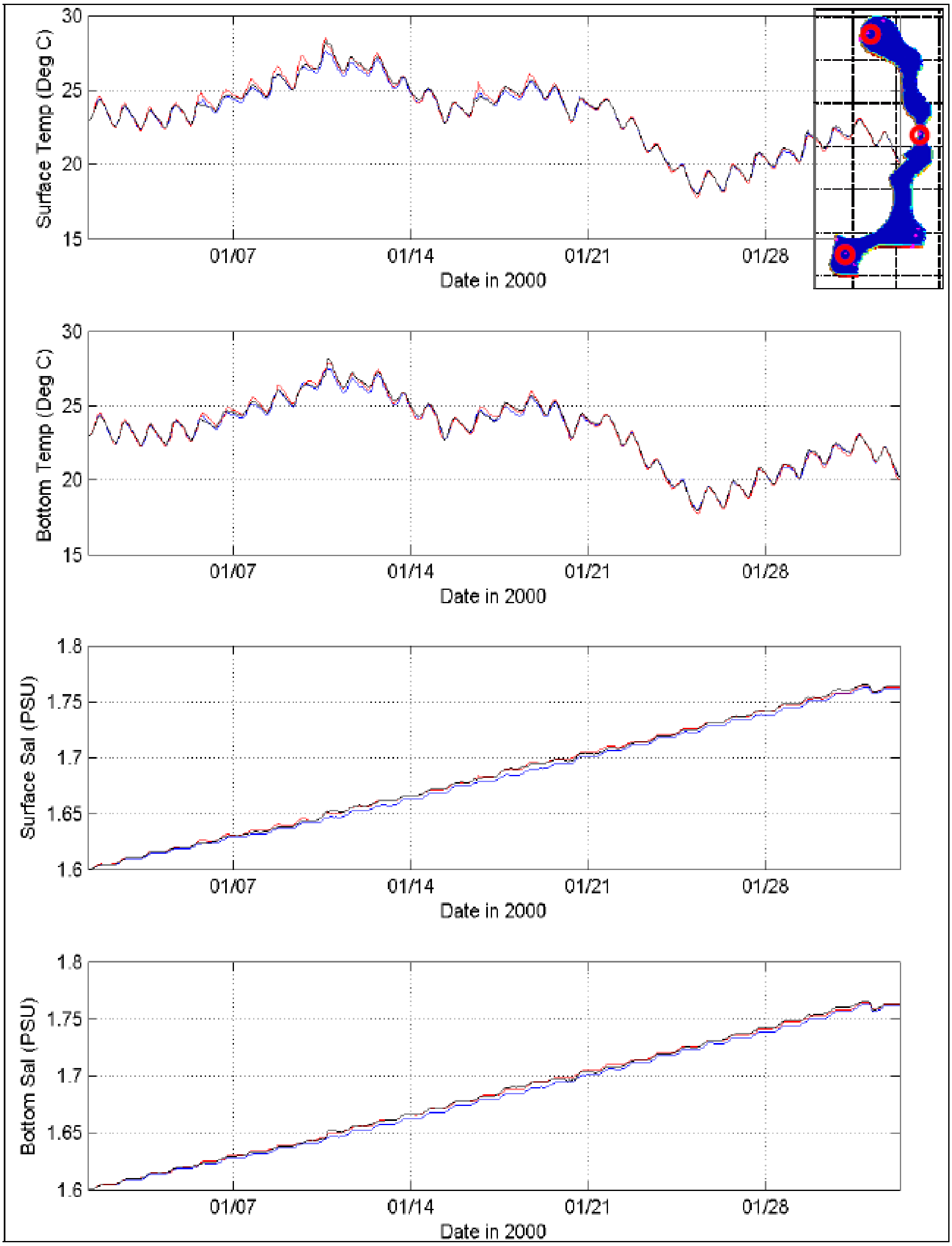


Figure 14 **Time-series Plots of Temperature and Salinity in the Surface and Bottom Layers in Summer.**

Stratification

Stratification prevents or hinders vertical mixing of the water column. Stratification occurs mostly in summer when solar heating and light winds enable a warm, less-dense surface layer to form on top of the cooler, denser and (usually) nutrient-rich deeper waters. If this is prolonged, biological activity in the bottom sediments can cause the bottom waters and sediment surface to become anoxic, creating conditions favourable to the release of phosphorus from the sediments.

Time-series plots of temperature and salinity through the water column for each seasonal simulation were used to assess the likelihood of stratification. Sample plots for the summer simulation are shown on Figure 15.

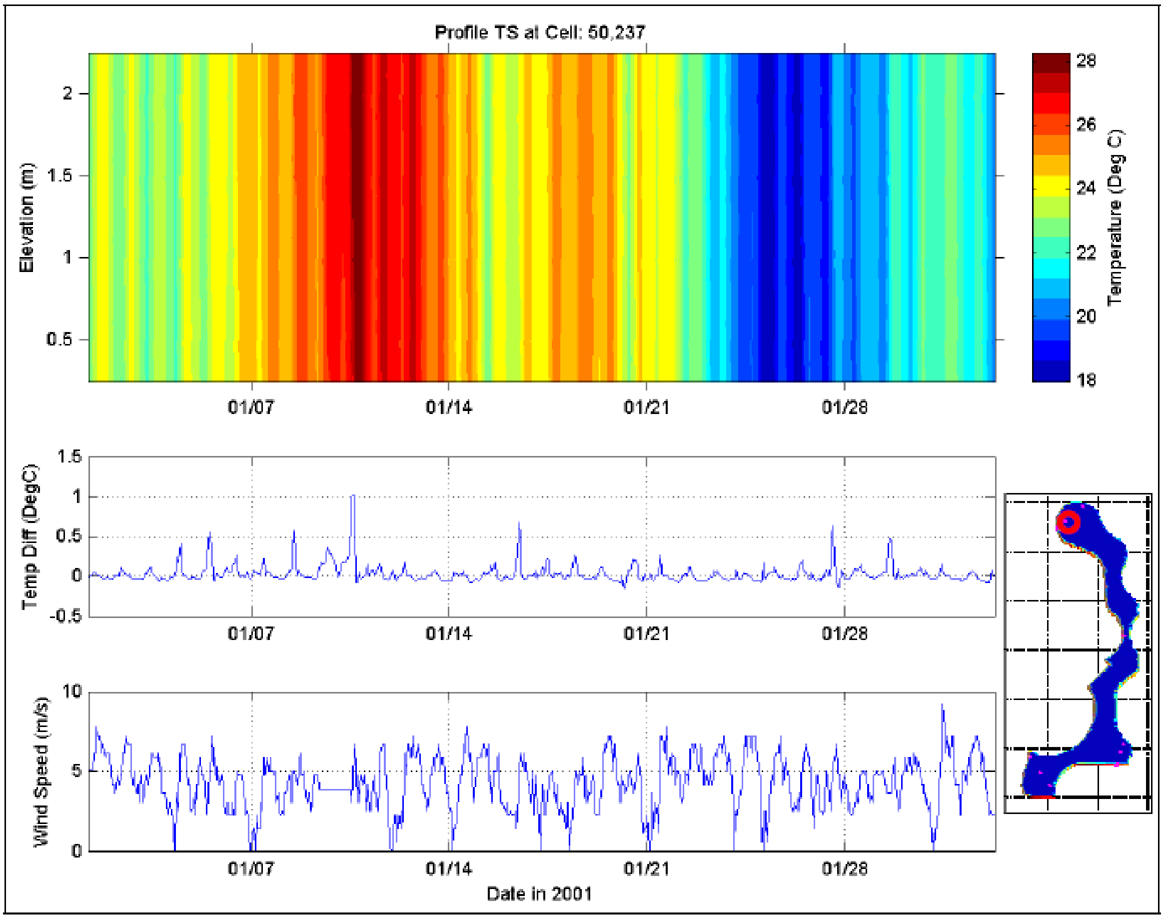


Figure 15 **Time-Series Temperature Profile (top) and Temperature Difference between Surface and Bottom Layers (middle) at Inflow Point in Summer. Wind Magnitude is shown in bottom panel.**

The plots show that the lake will be well mixed most of the time. Some temperature stratification is evident during daylight hours, but the lake cools and mixes at night. This type of stratification is not predicted to persist for longer periods. No significant salinity stratification is predicted. Longer-term (4.5 years) simulated temperature profiles generated by the DYRESM model are shown in Section 4.2.2.

3.5.3 Conclusions

The main conclusions from the circulation modelling are:

- The circulation in the lake will be predominantly driven by the wind. Autumn is predicted to have the least energetic circulation due to the generally lighter winds.

- Density-driven currents, due mainly to differential heating of the lake, will also influence the circulation but this effect is secondary to wind as the spatial variations in temperature and salinity are relatively small. The effect of the density-driven currents will only be apparent during low-wind periods in summer.

- Most of the time the lake will be well mixed vertically. Some thermal stratification is predicted during daylight hours, but convection will cause the lake to cool and mix on most nights.

- No significant salinity or temperature stratification is predicted.

- The horizontal and vertical variations in nutrient concentration are predicted to be minimal.

4.0 LAKE WATER QUALITY MANAGEMENT

4.1 Salinity

The simulated salinity graph on Figure 16 shows that the lake salinity will vary seasonally between a winter minimum (due to rainfall and roof runoff) of about 900mg/L TDS to a summer maximum (caused by bore water input and evaporation) of around 1,800mg/L. The salinity will peak in the first year after filling begins and then gradually decline as the area of roofs contributing runoff increases. The annual salinity cycle will reach semi-equilibrium by 2016 (based on 1987-2006 historical rainfall data) and will thereafter vary annually with rainfall and evaporation.

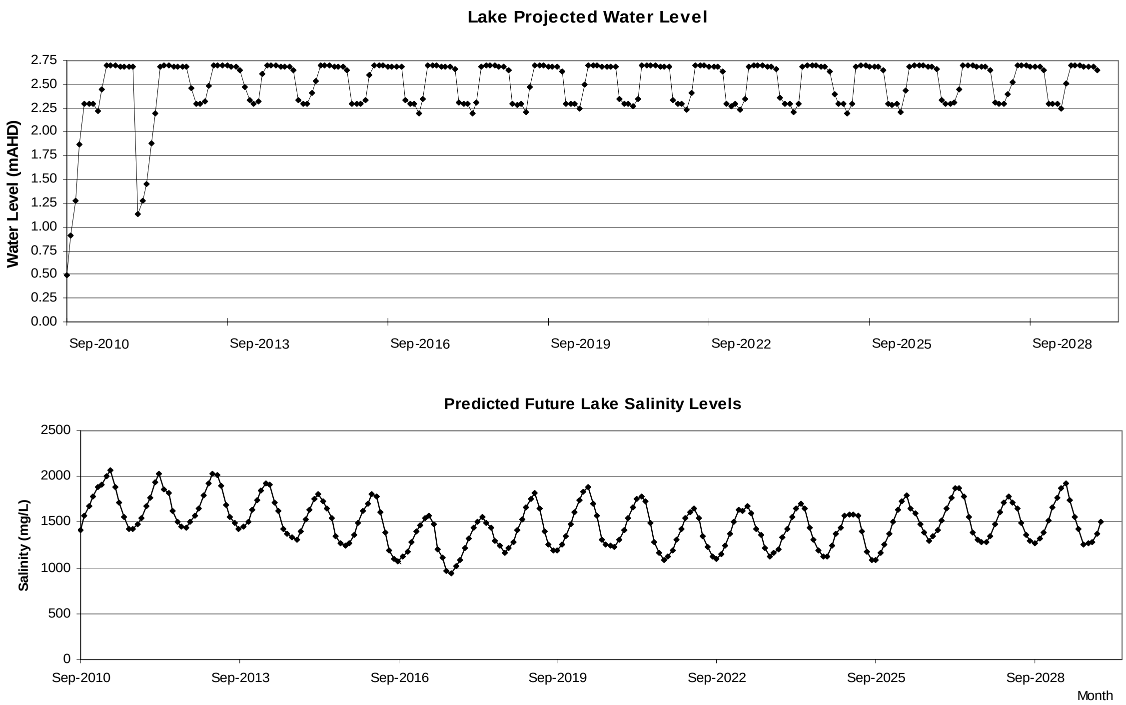


Figure 16 Predicted Lake Water Level and Salinity 2011-2029

The graph also shows that the salinity of the lake will be less than that of the bore water for at least the early part of summer, enabling the feature lake to be used as a superior source of irrigation water. Irrigation will switch to using bore water via the irrigation lake later in summer, when the salinity of the lake reaches or exceeds that of the bore water.

Table 4.1 shows a summary of average salt loads in the feature lake over the simulation period from January 2012 to December 2029. From an initial salt loading of 220 tonnes due to lake filling with bore water, the total salt load will gradually decrease at 2% per year until it reaches semi-equilibrium in about 2016. The table shows that the annual salt input is almost entirely due to bore water inflow, and is balanced by overflow and irrigation outflow.

Table 4.1 Modelled Annual Salt Loads 2012 - 2029

Component (all units in tonnes/year annual average)	**Salt Load**	**% of total**
Rain water input	3	1%
Bore water input	309	98%
Roof water input	3	1%
Total Inputs	**315**	100%
Irrigation output	-79	25%
Overflow output	-242	75%
Total Outputs	**-321**	100%
Net Salt Load	**-6**	**-2%**

4.2 Nutrients and Algae

4.2.1 Nutrient Inputs and Outputs

Given the need to maintain very high water quality in the feature lake, the minimisation of nutrient inputs to the lake is of critical importance. The key nutrient in fresh water bodies, and the principal regulator of biological productivity (including algae, aquatic plants and insects), is phosphorus. Excess phosphorus in fresh water bodies can give rise to algal blooms, excessive aquatic plant growth, high insect populations and other water quality problems. Nitrogen and organic carbon are less important but still significant nutrients.

The lake will receive phosphorus and other nutrients from inputs of bore water, rainfall and atmospheric fallout, water birds and occasional (less than once every 5 years) stormwater overflow from infiltration swales. Nutrients will leave the lake water via removal of water for irrigation, winter overflows and by immobilisation in the bottom sediments. Under certain conditions (notably, stratification), phosphorus released from the sediments may form a significant source of internal phosphorus loading. The characteristics and magnitudes of these phosphorus inputs and outputs are discussed below.

Bore Water

Testing of water from the exploratory bore drilled at the site in 2006 showed a total phosphorus concentration of 0.01mg/L and filterable reactive phosphorus (=orthophosphate) concentration of 0.003mg/L. With an average annual bore water input of 193 ML/yr, this will produce a loading of 1.93 kg/yr of phosphorus to the lake.

Rainfall and Roof Runoff

Rainfall contains very low concentrations of phosphorus; Hingston & Gailitis (1976) measured total P concentration of 0.001mg/L in rainfall in Perth. At this concentration, rainfall and roof runoff would together contribute 0.27 kg/yr of phosphorus to the lake.

Water Birds

Water birds have the ability to contribute a substantial proportion of nutrient loadings to water bodies, with the magnitude depending heavily on the type and population of birds, the proportion of their time spent on the lake and the proportion of their food sourced from outside the lake (faeces generated from feeding within the lake represents nutrient cycling, not input). Various researchers (e.g. Marion *et al.*, 1994; Mitchell & Wass, 1995; Bioresearches, 2002; Scherer *et al.*, 1995) have estimated that water birds contribute anything from 4% to 97% of the annual phosphorus inputs to different lakes.

Accurate estimation of water bird nutrient inputs is difficult as the population is difficult to predict and information regarding their nutrient generation is limited. Most of the information on bird nutrient generation found from an internet literature search was concerned with either Canada Geese on large North American lakes or domestic ducks on Asian aquaculture and rice farms. Both of these scenarios involve very large populations of birds ingesting large quantities of rich food.

The most significant potential source of bird-derived nutrient loads to the feature lake is related to the presence in certain seasons of large numbers of water birds including ducks, migratory waders and other species on Austin Bay in Peel Inlet, about 1.5km west of the site. If these birds exploited the feature lake as a convenient source of fresh water the temporary population on the lake could be large. This possibility is mitigated by the fact that, when the highest populations of birds are on Austin Bay, many are in moult and are therefore unable and/or disinclined to leave the estuary.

Previous work on water bird populations and nutrient inputs on local lakes is sparse. In the environmental assessment of Champion Lakes (RPS BBG, 2005), bird nutrient loadings were discounted on the grounds that most of the birds' food would come from the lake itself and therefore did not represent nutrient input, but simply cycling. In the case of Austin Cove, this is not considered valid, since the low bioproductivity of the feature lake will mean that little food will be available for water birds. Any birds resident on the lake will need to obtain most of their food from outside sources, even if this means foraging on the turf areas around the lake (which would otherwise contribute no nutrients to the lake).

The most relevant local examination of water bird numbers on Western Australian lakes found was Halse *et al.* (1993), which recorded the populations of 61 water bird species on 95 south-west wetlands and related these to wetland characteristics including salinity, emergent vegetation, water depth, permanence, pH, phosphorus concentration and wetland area. By collating the population data for those wetlands most closely resembling the feature lake (permanent fresh to brackish water, little vegetation, high water quality, small size), it is estimated that a population density of about 10 water birds per hectare (nominally assumed to be ducks) can be expected to occupy the lake.

The rate of nutrient generation by water birds was estimated from a number of Australian and overseas sources including the following:

- Mitchell & Wass (1995) estimated that black swans on a New Zealand lake produced 52g dry weight of faeces per bird per day, comprising 2.3% nitrogen and 0.44% phosphorus (of which 66% was in particulate form).

- Bioresearches (2002) estimated that mixed wild waterfowl in New Zealand produce 1.6% of their body weight in dry faeces each day, giving a total production for a 0.5kg Grey Teal of 2.8kg of faeces per year.

- The Government of Northern Ireland *Phosphorus (Use in Agriculture) Regulations 2006* assume a phosphate (P_2O_5) content of 0.55% in duck manure.

- The Australian Centre for International Agricultural Research (2001+) estimated that Asian domestic ducks produced 0.5 – 10kg of dry faeces per year containing 0.48% nitrogen and 0.61% phosphorus.

- The Idaho Department of Environmental Quality (200_) estimated that ducks on a water body on the Idaho River generated about 0.2 grams of phosphorus per bird per day.

- The Government of Canada (200_) estimated that mallard ducks produced 10kg dry weight of faeces each per year, containing 170 grams of phosphorus.

- Manny *et al.* (1975) estimated that a population of 2,100 Canada geese on a 15ha lake generated an average phosphorus loading of 28 grams per bird per day.

- Manny *et al.* (1994) estimated phosphorus loadings from a mixed population of 10,700 mallards and Canada geese on a 15ha lake at 8 grams per bird per day.

- Marion *et al.* (1994) estimated phosphorus loadings from a population of up to 2,435,000 water birds of various species on a 6,300ha lake at 1 gram per bird per day.

To simulate the potential faecal phosphorus loading from ducks and other water birds using the lake, a constant loading of phosphorus in the form of Particulate Organic Phosphorus Labile (POPL) at 92 grams per day was incorporated in the model. This loading rate simulates the faecal phosphorus load from a nominal population of 10 ducks per hectare occupying the lake, obtaining all or most of their food from external sources (including the Peel-Harvey Estuary, foraging in parkland surrounding the lake and feeding by humans) and depositing 50% of their faeces in the lake.

Values for water bird numbers, faecal loadings and the phosphorus content of faeces were obtained from a number of local and international sources including Halse *et al.* (1993), Jaensch *et al.* (1988), Government of Northern Ireland (2006) and State of Idaho (200_). The rate of 92 grams/day adopted for the modelling is considered to be towards the upper end of the range of estimates.

4.2.2 Nutrient and Algae Model Setup

The water quality of the feature lake was modelled using the one-dimensional hydrodynamics model DYRESM coupled with the aquatic ecological model CAEDYM. This coupling allows for investigations into the relationships between physical, biological and chemical variables in water bodies over seasonal and inter-annual timescales. A JAVA-based modeller was used to output the results. All software is freeware provided by the University of Western Australia's Centre for Water Research (http://www.cwr.uwa.edu.au/services/models.php?mdid=4). The CAEDYM package includes comprehensive processes of the C, N, P, Si and DO cycles, several size classes of inorganic suspended solids and phytoplankton dynamics (Hipsey *et al*., 2006).

Figures 17 and 18 below show the phosphorus and nitrogen cycles within the lake water body that are modelled by the CAEDYM package. The seasonal values for significant fluxes indicated with numbered arrows in Figures 17 and 18 are given in Figures 22 and 23.

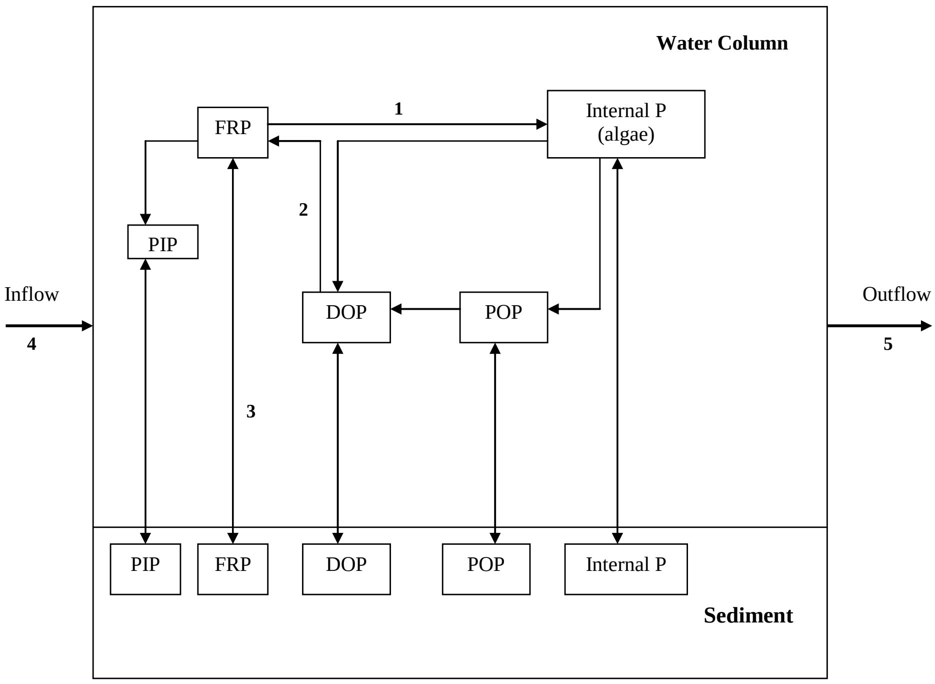


Figure 17 Lake Phosphorus Cycle

DOP = Dissolved Organic Phosphorus (labile)
FRP = Filterable Reactive Phosphorus
POP = Particulate Organic Phosphorus (labile)
PIP = Particulate Inorganic Phosphorus

Fluxes
1: Phytoplankton uptake
2: Mineralisation (DOP → FRP)
3: Sediment flux
4: Inflow
5: Outflow

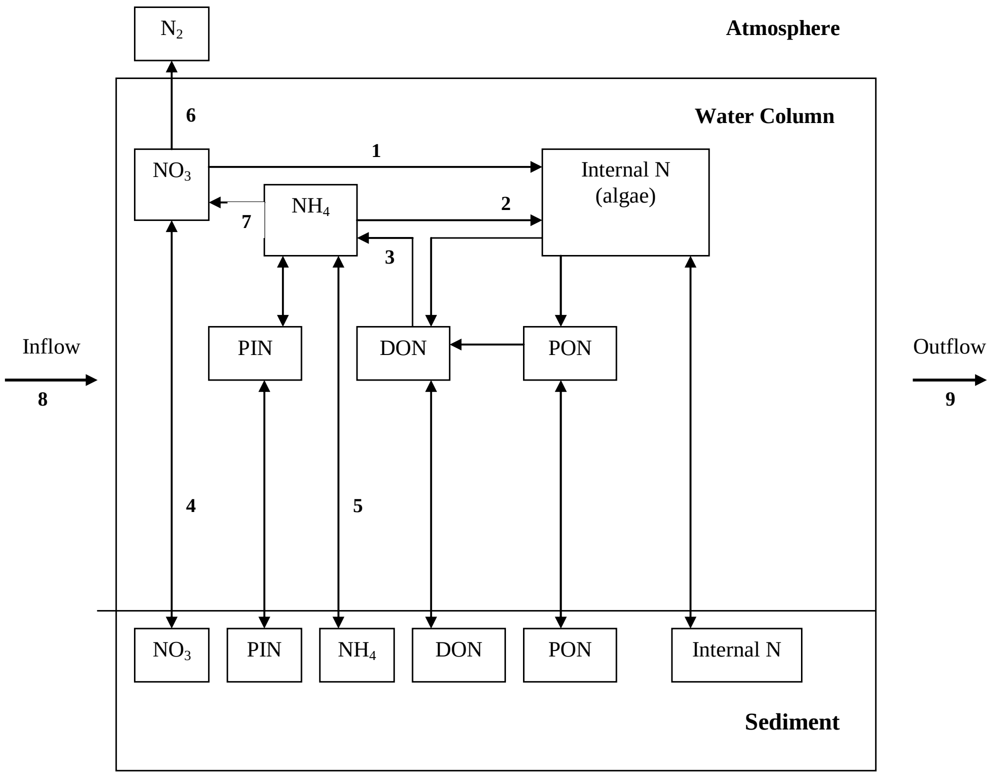


Figure 18 Lake Nitrogen Cycle

DON = Dissolved Organic Nitrogen (labile)
PON = Particulate Organic Nitrogen (labile)
PIN = Particulate Inorganic Nitrogen

Fluxes
1: N-NO_3 phytoplankton uptake
2: N-NH_4 phytoplankton uptake
3: mineralisation (DON → NH_4)
4: NO_3 sediment flux
5: NH_4 sediment flux
6: Denitrification
7: Nitrification
8: Inflow
9: Outflow

The water nutrient and chlorophyll-*a* concentrations in the lake were modelled over a representative 4.5-year period beginning in June 2012 when both parts of the lake have been constructed and the lake is full, incorporating actual monthly rainfall for the years 1987 to 1991 and evaporation data for 2002 to 2006. These years represent a range of annual rainfall from 825mm to 1,048mm, compared to a long-term (20 year) average of 840mm for the region. The water quality for bore water and rainfall were applied using the values described in Section 5.4.1 of the Urban Water Management Strategy (BES and JDA, 2007).

Because the lake is designed to only receive stormwater overflow from a greater that 5 year ARI storm, the nutrient model does not include any nutrient or water loadings from stormwater. To model the effect of inflow of runoff from a 10-year 72 hour ARI storm, a simulation was run with a storm water inflow of 0.15 m^3/s (based on the stormwater modelling) for three days in July 2014 (corresponding to 2-4 July 1991 rainfall data).

The nutrient content of the storm water was assumed to be 0.22mg/L NO_3, 0.34mg/L NH_4, 0.1mg/L PO_4, 1.5mg/L TKN, 0.68mg/L TP and 1.5mg/L TN (WESROC, 2007).

Other inputs to the model included:

- An initial (hypothetical) temperature profile (day 153 year 2012).
- An initial water quality which includes chlorophyll-*a* of 0.01µg/L, DO of 8.1mg/L, PO_4-P of 0.005mg/L, Particulate Organic Phosphorus Labile (POPL) of 0.005mg/L, NO_3-N of 0.005mg/L, NH_4-N of 0.01mg/L and pH of 7.5.
- One-dimensional lake bathymetry.
- Daily meteorological fluxes consisting of:
  - measured solar radiation 2001-2005 (by satellite over Mandurah)
  - measured cloud cover 2000-2004 (Perth Airport)
  - measured air temperature and wind speed 2001-2005 (Mandurah)
  - measured evaporation 2002-2006 (Medina)
  - measured rainfall 1989-1993 (Pinjarra), corresponding with the period used in the water balance and salt modelling.
- Daily inflow (bore water and roof runoff water) with water quality as described in previous sections and assumed constant throughout the simulation, except for a 3 day period in the study of the storm runoff water effect. Temperature of bore water was assumed to be a constant 23^{o}C (Groundwater survey of Leederville Aquifer 2001). The temperature of roof runoff water was adapted from air temperature by taking into account the height of the measurement station (8m) and surface water-air drag coefficient using Tennessee Valley Authority method (1972).
- A phosphorus (as POPL) input of 92mg/day to simulate the faecal nutrient load contributed by water birds.
- Daily outflow to irrigation.

The volumes and salinity of inflows and outflows were estimated from the water balance and salt modelling. All meteorological flux values are plotted in Appendix C.

The ecological state of a water body is governed by three principal factors:

- physical state (turbulence, light penetration, temperature);
- chemical state (ionic strength and composition, nutrient availability); and
- biological state (species composition, growth and grazing).

These factors act at different time scales. Under steady-state conditions, the ecological state varies in response to changes in the wind stress and surface heating, which usually occur in cycles of several hours to several days. The relatively short time scale of these two meteorological components makes them important for lake dynamics. In winter, low light availability, low temperature and complete vertical mixing of the water column typically override biological and chemical factors. In spring and summer, water temperature, light intensity and water column stability increase as the irradiance increases.

The results of the modelling are described in full in Appendix C and summarised below.

4.2.3 Nutrient and Algae Modelling Results

Typical seasonal patterns predicted by the model for temperature, orthophosphate (PO_4-P) concentration and chlorophyll-*a* in the lake are shown on Figures 19-21. The contours for other parameters are given in Appendix C. The algal growth is determined by a non-linear function of the water temperature and the nutrient availability.

Lake dynamics is determined primarily by the seasonal fluctuation of solar heating and wind forcing. Due to maximum solar heating and minimum rainfall, the temperature reaches a maximum in summer. However, inflow of relatively dense (due to higher salinity) bore water and moderate wind speeds prevent the lake water column from stratifying. The prevailing summer south-westerly wind that blows along the axis of the lake also helps to maintaining mixing throughout the year, as shown on Figure 19.

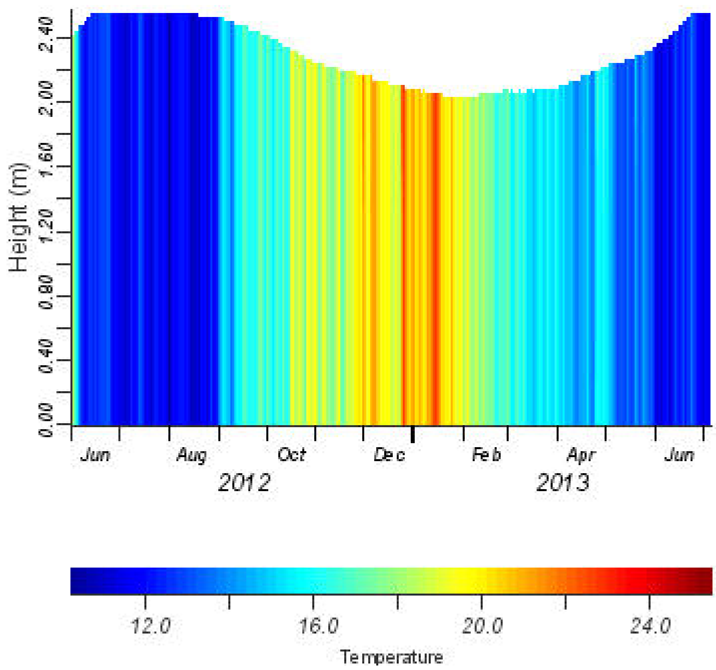


Figure 19 Simulated Temperature (°C) June 2012 – June 2013

Figure 20 shows that the orthophosphate concentration of the lake reaches a seasonal maximum of just under 0.035 mg/L in mid-summer 2016, falling (due to sedimentation and flushing with rainfall and roof water) to less than 0.006 mg/L in winter. The summer maximum is slightly above the trigger level for algal growth, but well below the level at which phosphorus ceases to be limiting to algal growth (about 0.05mg/L). The Total Phosphorus concentration is expected to be low throughout the year, with a maximum of about half of the Freshwater Guideline of 0.06mg/L. Nitrogen levels are also predicted to remain low throughout the year.

Figure 21 shows that chlorophyll-*a* levels in the lake are expected to remain below 2.2μg/L throughout the year. This is well below the level of 10μg/L that is typically taken as indicating algal bloom conditions.

Chlorophyll-*a* is a commonly used indicator of algal population density; values of 10μg/L or more are commonly considered to indicate algal bloom conditions. A target limit of 10μg/L is commonly applied to urban lakes and waters used for primary and secondary contact recreation (AEC, 1987; Queensland Health, 2001; Environment ACT, 1997).

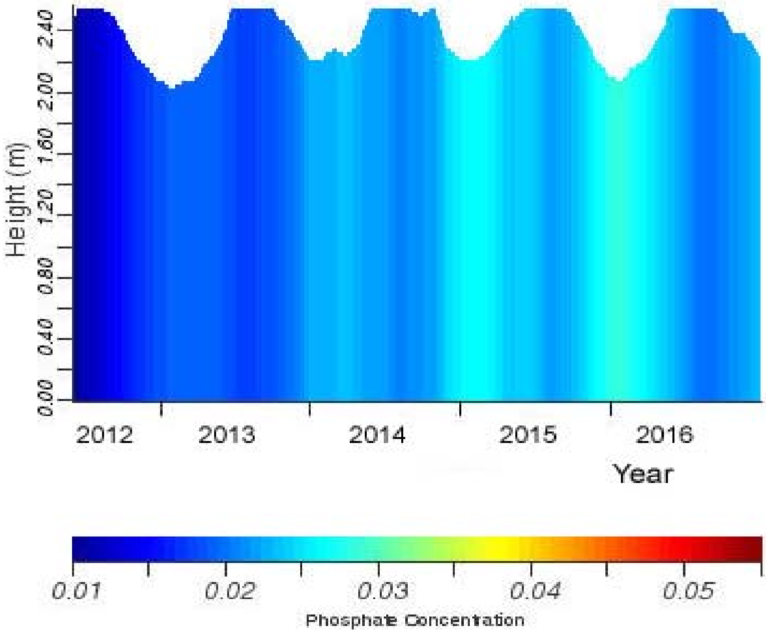


Figure 20 Simulated PO_4-P Concentration (mg/L) June 2012 – December 2016

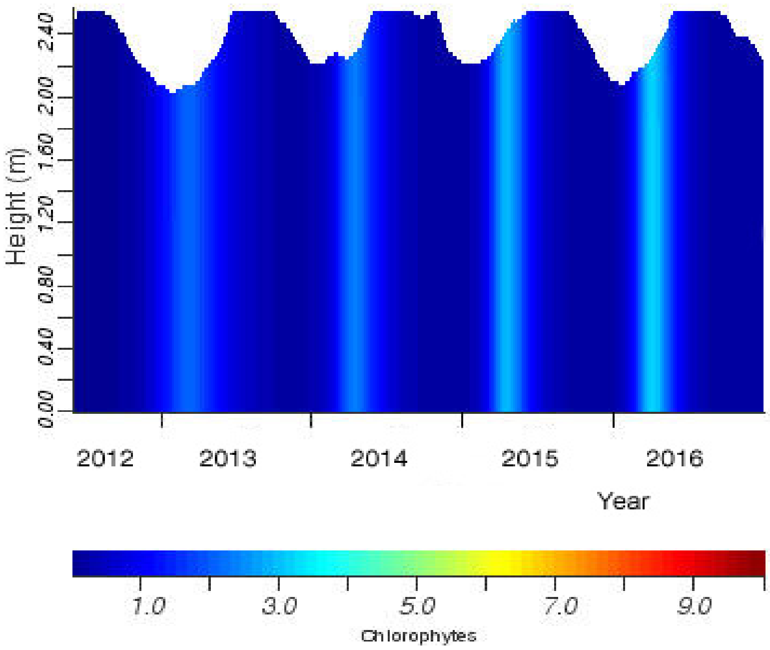


Figure 21 Simulated Chlorophyll-*a* Concentration (μg/L) June 2012 – December 2016

The conclusion from the nutrient simulation is that the water quality of the lake is expected to be high and to meet the Freshwater Guidelines throughout the year.

Seasonal fluctuation of Nutrient Loadings

The seasonal PO_4-P mass in the lake, as shown on Figure 22, is predominantly controlled by the algal uptake. The PO_4-P loading in the lake (blue squares in Figure 22 with a scale on the right) shows a significant relationship with the biological uptake of PO_4-P by the algae (as a sink) and the mineralisation of dissolved organic particulate phosphorus (DOP) to PO_4-P (as a source). In summer months, when sunlight is at its maximum, the algal growth reach its peak and consumes PO_4-P; this phosphorus will then be stored as internal phosphorus in algal cells. As a consequence, the PO_4-P loads in the water decrease significantly in period of March-May. During winter period the algae grow slowly so that at the end of spring the biological uptake of PO_4-P by algae reaches similar loads as the outflow. A relatively constant mineralisation during the period of winter-early summer increases the PO_4-P in the water.

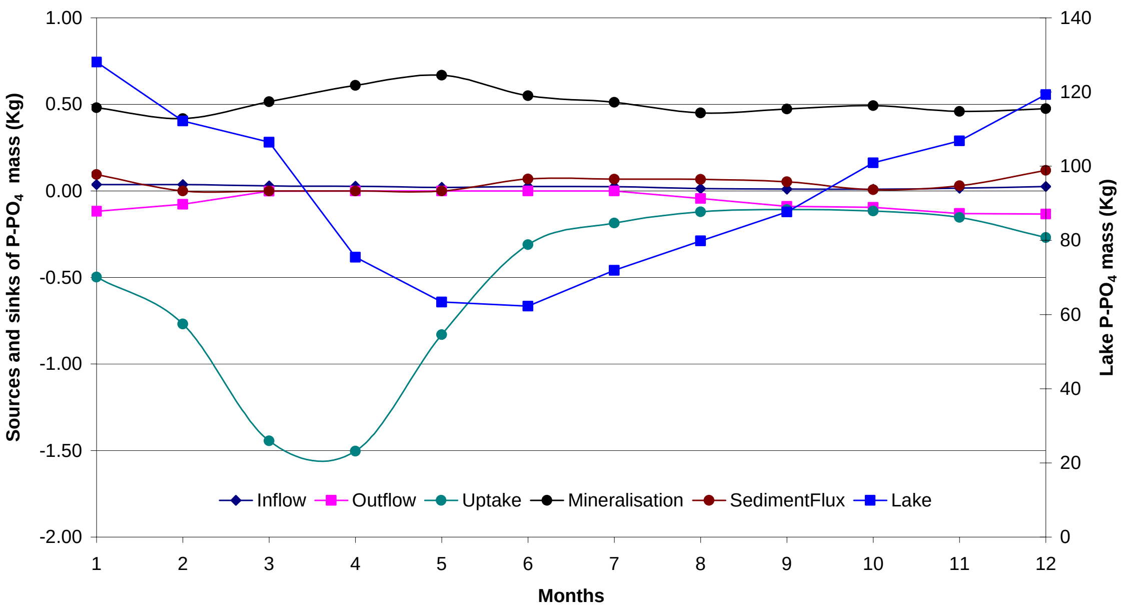


Figure 22 **Monthly Average (January - December) PO_4-P Sources and Sinks (positive values represent sources, negative values represent sinks)**

Similarly, the seasonal NO_3-N load in the lake, as shown on Figure 23, is also predominantly controlled by the algal uptake. The NO_3-N loading in the lake (blue squares in Figure 23 with scale on the right) shows a significant relationship with the biological uptake of PO_4-P by the algae (as a sink). Unlike the phosphorus loading, the flux of NO_3-N into the sediment becomes a significant secondary sink.

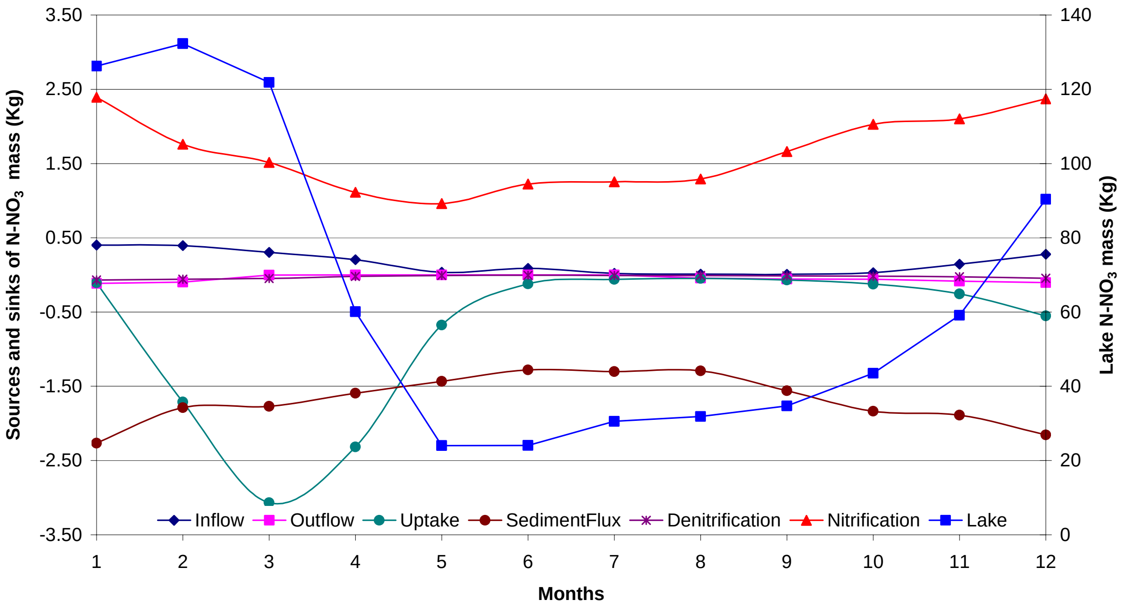


Figure 23 **Monthly Average (January - December) NO_3-N Sources and Sinks (positive values represent sources, negative values represent sinks)**

Effect of Bird Faecal Phosphorus Loads

Comparison of the simulation results with and without Particulate Organic Phosphorus Labile (POPL) of 92g/day from bird excreta indicates that bird faeces contributes an estimated 65% of the total orthophosphate load in the lake water. However, the comparison shows that this additional increment of phosphorus gives rise to only an additional 0.4μg/L of chlorophyll-*a* in the water column. This suggests that the chlorophyll-*a* concentration is relatively insensitive to bird faecal inputs, possibly because the particulate nature of the faecal phosphorus makes it less available to algae and promotes its early removal from the water column by sedimentation. In this case, a bird population greater or less than that estimated should have relatively little impact on the water quality of the lake. The phosphorus simulations shown on Figures 24 and 25 include a daily input of 92g/day from bird faeces.

Overpopulation and other bird-related problems could arise if regular feeding of birds takes place at or near the lake. This can best be combatted by a combination of public education (by leaflets etc.) and signage around the lake requesting people not to feed the birds. Measures to limit bird numbers are discussed in Section 5.3.

Effect of 10-year ARI Storm Water Runoff on Nutrients and Chlorophyll-a

Storm water overflow from a 10-year ARI storm represents a potentially significant pulse of nutrient inputs to the lake. A season in which 10-year ARI storm flows enter the lake may be considered a near worst-case scenario for the lake water quality. Modelled PO_4-P and chlorophyll-*a* concentrations with 10-year ARI storm water inflow are shown on Figures 24 and 25. The figures show that the nutrient input from storm water creates a second peak of chlorophyll-*a* concentration (2.6μg/L) in the winter of the storm, but the concentration has declined to normal levels before the following summer.

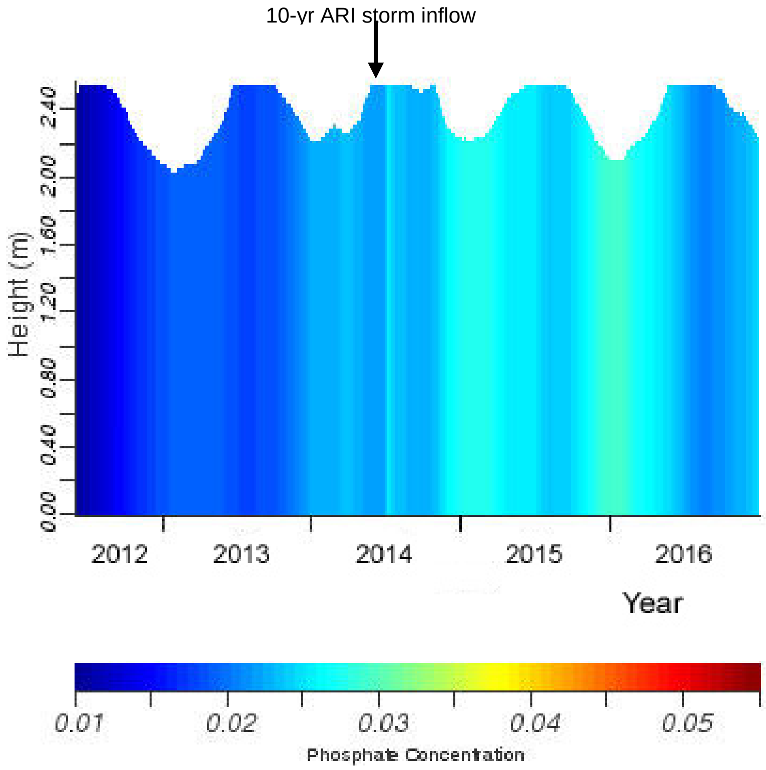


Figure 24 **Simulated PO_4-P Concentration (mg/L) June 2012 – December 2016 with 10-year ARI Storm Runoff in Year 2014**

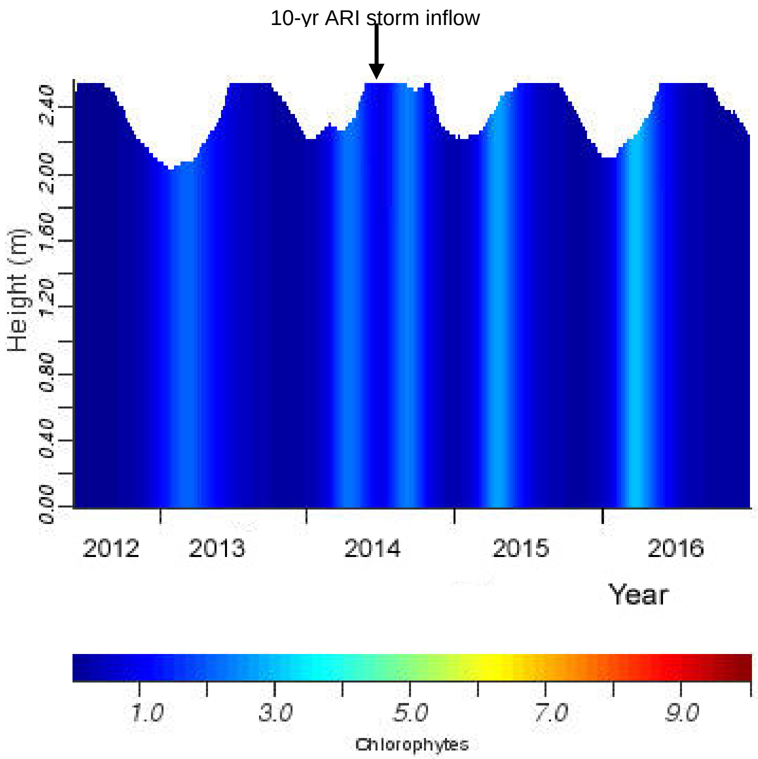


Figure 25 **Simulated Chlorophyll-*a* Concentration (μg/L) June 2012 – December 2016 with 10-year ARI Storm Runoff in Year 2014**

4.3 Microbiological Water Quality

The water quality of the feature lake will be managed to ensure that pathogenic micro-organisms are not present in sufficient numbers to cause health problems through incidental contact with the lake water. The water quality will be maintained at a level suitable for secondary contact recreational waters, as set out in the *Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters* (ANZECC, 2000).

This standard of water quality will enable the lake to be safely used for water-based activities that involve “incidental” contact with the water, including splashing, wading and occasional full immersion. The types of use included in this category include recreational boating, rowing, canoeing, sailboarding, model boating and wading. They do not include full (primary) water contact activities such as swimming and diving.

The secondary contact recreational water quality standards focus primarily on limiting the populations of pathogenic (disease-causing) micro-organisms including bacteria, protozoa and viruses. The standards are based on the populations of two common and readily-measurable indicator species: faecal coliforms and enterococci, for which the limits (ANZECC, 2000) are:

- Faecal coliforms: 1000 organisms/100 mL (minimum of five samples taken at regular intervals not exceeding one month, with four out of five samples containing less than 4000 organisms/100 mL)
- Enterococci: 230 organisms/100 mL (maximum number in any one sample: 450–700 organisms/100 mL).

The ANZECC (2000) guidelines also specify a number of other quality parameters relevant to secondary contact waters:

- Macrophytes, phytoplankton scums, filamentous algal mats, sewage fungus, leeches etc., should not be present in excessive amounts.
- Algal populations should be less than 15,000–20,000 cells/mL (depending on the species).
- Large numbers of midges and aquatic worms should be avoided.
- The natural visual clarity should not be reduced by more than 20%.
- The natural hue of the water should not be changed by more than 10 Munsell points.
- The natural reflectance of the water should not be changed by more than 50%.
- The pH of the water should be within the range 5.0–9.0, assuming that the buffering capacity of the water is low near the extremes of the pH limits.
- The waters should not contain any chemicals that are either toxic or irritating to the skin or mucous membranes.
- Oil and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour.

In addition, the ANZECC (2000) guidelines set recommended levels for over 150 other organic and inorganic chemicals and pesticides in recreational waters.

Because almost all of the water in the lake will be sourced from artesian groundwater, rainfall or roof runoff, there will be little opportunity for most of the contaminants of concern to enter the lake. The most likely sources of nutrients and other contaminants will be water bird and domestic animal faeces, leaf and other litter, human contact, bird feeding and occasional stormwater overflow. These sources will be minimised as follows:

- The lake surrounds (paths, grassed areas etc.) will be graded away from the lake so that runoff from these areas (and entrained contaminants such as fertilisers, sediments and animal faeces) cannot enter the lake.

- Fertilisation of lawns and gardens near the lake will be carefully controlled to avoid overspreading into the lake.

- Signs will be erected around the lake requesting people not to feed water birds or drop litter into the lake.

- Tree species that drop large numbers of leaves will not be planted close to the lake.

- Litter bins and "doggie dumpage" disposal bags will be provided at regular intervals around the lake to encourage people to dispose of wastes responsibly.

- Storm overflows from 5+ year ARI storms will be pre-treated by detention in the primary infiltration swales before being allowed to overflow to the lake.

- The high density of housing and other development around the central POS will create a high level of surveillance, thereby discouraging littering and other antisocial activities that might lead to contamination.

- Roof drainage systems on those houses and other buildings draining direct to the lake will be configured with no openings at ground level, so as to prevent or hinder the disposal of contaminating materials (paints, oils etc.) into the roof drains.

- Periodic sanitary inspections will be conducted on the surrounding areas of the lake, noting the general cleanliness of the area, the condition of the lake, the number of dogs visiting the area and the incidence of uncollected faeces in the surrounding areas.

- Pamphlets will be distributed to surrounding residents, highlighting the causes and consequences of microbial contamination and providing "what you can do" advice to protect the lake water quality.

Lake water quality will be monitored at least monthly for a range of physical, chemical and biological parameters. Details of the monitoring programme are given in Section 7.1.3.

5.0 FLORA AND FAUNA MANAGEMENT

5.1 Algae

Control of algal growth in the lake will be primarily achieved through the minimisation of nutrient inputs as described in Section 4.0. The modelling described in Section 4.2 indicates that, given the expected nutrient inputs, the level of algal growth is predicted to be well below the level at which problems arise for ecological, recreational or aesthetic use.

In the event that algal growth does become excessive, a number of physical or chemical control options are available. These are discussed in Section 8.3.

5.2 Aquatic Plants

Excessive growth of aquatic plants such as Asian bulrush (*Typha orientalis*), water lilies, ribbon weed and others is undesirable in recreational lakes for the following reasons:

- Heavy plant growth can create obstructions that interfere with boating and other recreational uses.

- Plants can obstruct or foul mechanical equipment such as irrigation and circulation pumps, fountains and water level controllers.

- Excessive plant growth can be unsightly, both in itself and as a collection point for floating litter.

- Very heavy growth can locally restrict water circulation and cause night-time deoxygenation of the water column, leading to release of phosphorus from the sediments.

- Dense growths can also provide refuge and breeding grounds for mosquito larvae and other nuisance insects.

Like algae, aquatic plant growth is determined by the eutrophic status of the lake. The management of nutrient levels will therefore be the primary means used to control the growth of aquatic plants in the lake. In the case of the Austin Cove lake, the ability of these plants, most of which are bottom-rooted, to invade will be limited by the lake's depth and by the presence of the plastic liner. However, with time, an organic-rich sediment layer will accumulate that may support rooted plants in the shallower areas.

In the event that aquatic plant growth becomes a problem, a number of control measures are available, including periodic harvesting and chemical control. These are discussed in Section 8.4.

5.3 Water Birds

Water birds are the largest potential source of nutrients to the lake, as well as being a direct source of faecal coliforms and other pathogenic bacteria. Maintenance of a moderate to low bird population is therefore crucial to maintaining high water quality in the lake.

The nutrient modelling presented in Section 4.2 incorporated estimated faecal phosphorus loadings from a population of 10 water birds (nominally ducks) per hectare, or about 160 on the whole lake. This population is considered to a reasonable approximation of the expected population given the size, location and ecological characteristics of the lake, although data on local lake bird populations are scarce.

In addition to their impact on water quality, water birds can cause other problems. Some introduced species, notably Mallards, can cause problems by interbreeding with native ducks. Black Swans can become a hazard due to their aggressive behaviour if present in large numbers, particularly if they are accustomed to being fed.

Overpopulation and other bird-related problems are only likely to arise if regular feeding of birds takes place at or near the lake. Bird numbers on the lake will be limited by:

- the physical characteristics of the lake, including extensive open water, mostly hard edges, limited cover and limited feeding opportunities; and

- extensive signage and resident education advising against feeding.

If, despite these measures, the bird population on the lake grows to undesirable levels, more direct methods of discouraging birds are available. These are discussed in Section 8.5.

5.4 Fish

Because the lake is a marginally fresh (1,100 – 1,800 mg/L TDS) water body, the fish that might survive to become a nuisance there will be essentially fresh water species

Introduced fish such as common carp, goldfish and koi (all varieties of carp) as well as other species such as mosquitofish (*Gambusia affinis*/*G. holbrooki*) are introduced into water bodies by various means, including people disposing of unwanted aquarium fish. Carp are very destructive to aquatic ecosystems due to their high reproduction and growth rates, their tolerance of low water quality (including low dissolved oxygen concentration) and their "vacuum cleaner" feeding method, which disturbs the bottom sediments, uproots aquatic plants and promotes nutrient mobilisation. Large carp can also pose a danger to waterbirds. Mosquitofish, though small, are aggressive predators of small native fish including the western native minnow (*Galaxias occidentalis*).

Both carp (goldfish) and mosquitofish are already present in tributaries of the Peel-Harvey estuary, including Bancell Brook and the Harvey Main Drain (Morgan & Beatty, 2003). Because both are fresh or brackish water species (carp tolerate up to 1/3 seawater salinity, while mosquitofish can tolerate up to seawater salinity for short periods), they are unable to persist in the Peel-Harvey estuary, which reaches salinities of up to 140% that of seawater in summer (Aust. Govt, 2006).

Because the Austin Cove lake will be maintained in a very low-nutrient state, there will be little food to support fish populations of any kind. Therefore, although it is likely that fish will be introduced into the lake at some stage and by some means, it is unlikely that their population will ever reach such a level as to create a nuisance.

Routine visual monitoring (Section 7.6) will determine whether fish are becoming a problem in the lake, although detection of fish is generally only possible when populations have built up to substantial levels. A range of control measures are available and are discussed in Section 8.6.

5.5 Insects

Insects, including mosquitoes and midges, are a feature of all lake environments and form an essential part of the aquatic food chain. The number of insects breeding at a particular lake depends on the productivity of the water body (mostly a function of nutrient availability) and physical characteristics such as the presence of extensive areas of shallow or still water.

In the case of the Austin Cove lake, the potential for significant mosquito or midge nuisance will be minimised by:

- the absence, at least in the early years, of a organic-rich sediment layer;
- the low phosphorus content of the inflowing water;
- the continuous circulation and aeration of the water body;
- the relatively constant water level;
- the absence of extensive areas of shallow water;
- the absence of dense vegetation between the lake and nearby houses; and
- the design of the development, including the use of non-insect attracting street lighting and the orientation of streets and spaces to encourage “wind flushing”.

Further details of the measures to be used to minimise mosquito nuisance and health risks are provided in the Mosquito Management Plan (RPS BBG, 2006).

Regular visual monitoring and public correspondence will be the main means used to detect insect nuisance at the lake. Because most programmed maintenance activities will occur during regular business hours while insect nuisance is generally worst in the evenings, public feedback will be of greater importance in relation to insects than for other lake parameters.

6.0 LAKE INFRASTRUCTURE MANAGEMENT AND MAINTENANCE

The lake water quality and hydrology have been designed so as to be as nearly as possible maintenance-free, with the only normal management inputs being monitoring of the automatic systems that control water levels and irrigation outflows, plus periodic monitoring of water quality and ecological state.

The physical structures of the lake and ancillary equipment will require periodic maintenance in accordance with equipment specifications. These maintenance activities will include:

- periodic (probably annual) inspection of irrigation pumps, fountains, bore pumps, cleaning of pump screens;
- scheduled servicing and eventual replacement of pumps and fountains;
- inspection and repair as necessary of lake walls, liner, boardwalks and other structures; and
- regular surveillance and removal as necessary of litter and aquatic plants.

These maintenance activities will be carried out by the Satterley Property Group until five years after the completion of lake filling, after which they will be handed over to the Shire of Murray.

6.1 Lake Liner

The synthetic liner fitted to the lake is not expected to require any routine maintenance other than annual water balance monitoring to confirm its integrity.

In the event that a failure in the lake liner occurs (as revealed by an excess of inflows over outflows), locating the damage is a simple and inexpensive task. Typically any damage to the liner occurs as small holes (2-5cm) and these are generally self-sealing resulting in very limited leakage.

Locating the failure can be achieved using an electrostatic probe and meter which locates a leak through changes in water pressure. This can be done simply by walking around the perimeter of the lake and inserting the probe at regular 20m intervals. Locating holes can also be accomplished through simple visual inspection of the upper margins of the lake where damage may typically occur. If repair is required, this can normally be carried out *in situ* without the need to drain or dry the area under repair.

6.2 Bores and Pumps

All bores, pumps, suction screens, pump frames, pipe work and aeration systems will require annual inspection and/or servicing to ensure they remain in peak working condition.

- *Bore Pumps, Irrigation Pumps & Circulation Pumps*

All pumps will be Grundfos 3hp, 415volt, 50Hz submersible pumps, of 304 stainless steel construction. The pumps will be checked in conjunction with the more frequent inspections that would apply to the irrigation pumping system. The circulation pumps ideally should be checked every six months and the bore and irrigation pumps every 12 months for the following:

1. Compare pump flow and pressure against published performance.
2. Megger the motor windings and record insulation resistance.
3. Monitor the motor temperature whilst running via the MTP 75 unit in the control cabinet.
4. Monitor the running amps.

Most of the above can be carried out by inspection of the gauges located in the control cabinet. If any change is noticed in operating temperature of the motor it would be prudent to take the pump out of service and check it over. The pump should be removed and checked every three years, and the screen should be inspected annually and cleaned if required. A major overhaul would be required possibly every ten years depending on the quality of the water. The pumps will generally have a service life of 15,000 hours before requiring an overhaul. The cost of the overhaul would be in the region of 40% of the capital cost of the pump motor.

The suction screen will be constructed from HDPE and supported by a hot dip galvanised frame. The HDPE screen has a 9mm aperture and the velocities through the screen will be such as to deter any material from being held against the screen. The screen is constructed from a non corrodible material and it is not expected that there will be a maintenance requirement for the screen itself, apart from checking on an annual basis that no obstruction or restriction of the screen has occurred. The hot dip galvanised frame should be monitored for any corrosion. If corrosion is found it should be removed and re galvanised. The screen and frame slip over a circular concrete pit and it is easily removed for maintenance by floating it to the surface with an air bag. Costs for inspection will amount to a few hundred dollars per annum for a diver to carry out a routine inspection.

- *Pump Support Frames*

The pump support frames will be constructed from hot dip galvanised steel. On an annual basis it would be prudent to inspect the frame and its fixings for corrosion and the security of all fixings. If any corrosion is found it should be cleaned down and a suitable anti corrosion coating applied.

- *Pipework*

The irrigation pipework will be generally rubber ring jointed PVC. Very little if any iron or solids are expected in the system and it is not expected that there will be any long-term maintenance or inspection requirement for the pipe work.

- *Aerators*

Surface aerators (fountains) will be employed to act both as aesthetic features and to assist in vertical mixing of the water body. Other aeration features such as ceramic aeration diffuser systems, which pump air into the lake via slotted pipes installed on the lake floor, will be provided as backup to assist in maintaining mixing if required.

Surface aeration units, such as Brindabella's fountains, will require the screens to cleared at least four times per year to remove leaf litter or rubbish that can be drawn into the device. This is undertaken by either accessing the aerator from a boat or fixing the aerator on a pulley system that allows it to be pulled to the lake edge for servicing.

The sub surface aeration systems only blow air into the lake via the pumps installed as part of the bore and wet well system. Annual servicing of the pumps is required to ensure they remain in peak working condition. A major overhaul may be required every five years but will be dependent on operating conditions. The costs associated with that would be about 40% of the capital value of the motor.

6.3 Public Facilities

All the public facilities that are proposed to interface directly with the lake, such as boardwalks and boat launching facilities, will require annual maintenance as part of the routine landscape maintenance regime of the adjoining open space areas. These facilities will be of robust construction, employing long life materials that will minimise maintenance requirements.

Boardwalks and boat launching facilities will be constructed of all metal posts, bearers and joists, with only the decking being possibly of timber. The metal components will be hot dip galvanised to minimise corrosion in accordance with the appropriate Australian Standards. These components typically have no or minimal annual maintenance requirements. Timber decking will require annual maintenance including oiling or sealing of the timber to maintain its structural integrity and longevity.

6.4 Litter Removal

General maintenance will be required to remove windborne rubbish and leaf litter from the lake and surrounding area. It is anticipated that this will need to be undertaken fortnightly, typically in conjunction with maintenance of the surrounding open space areas.

Gross pollutants that are disposed of into the lake by humans will need to be removed from the lake on a periodic basis. This is typically undertaken through visual inspection at the time of undertaking normal maintenance requirements of the surrounding open space.

7.0 MONITORING PROGRAM

7.1 Inflows and Outflows

Continuous monitoring of inflows and outflows will be undertaken by recording of pump operating hours combined with known pump performance characteristics. The lake supervisor will maintain a log of running hours of both the lake supply bore and the irrigation pumps. Lake overflows will be calculated by combining continuous records of lake level with the known flow characteristics of the overflow weir or flume. Stormwater inflows will be estimated using rainfall data and opportunistic observations of the duration of infiltration basin overflows.

These data will be combined each year with Bureau of Meteorology rainfall and evaporation data to produce an annual water balance for the lake. Any significant excess of inflows over apparent outflows without a corresponding change in lake storage will trigger an investigation into possible leakage.

7.2 Water Quality Monitoring

7.2.1 Bore Monitoring

The water quality of the bore supplying water to the lake will be monitored regularly for the following parameters:

- pH, EC
- Total and dissolved Iron
- Hardness (as $CaCO_3$)
- Nutrients: TP, FRP, TN, NO_X, TKN
- Heavy Metals: Al, As, B, Cd, Cr, Cu, Fl, Pb, Mn, Ni, Zn.

Monitoring of groundwater water quality will be undertaken quarterly in the first year after establishment and then six-monthly in subsequent years. Salinity and pH in the water supply bore will be monitored monthly from September to May in the first year after establishment and then quarterly in subsequent years.

The bore water sampling results will be compared with values obtained from the test bore prior to development and with the ANZECC (2000) water quality guidelines for secondary contact recreational waters. If the level of any key parameter exceeds the guidelines or the pre-development levels on two consecutive occasions, additional investigations and/or contingency actions will be implemented as described in Section 8.2.1.

7.2.2 Stormwater Monitoring

Stormwater runoff entering the lake from 5+ year ARI storm events will be sampled either through opportunistic grab sampling or rising stage samplers installed in the overflow channel(s). The purpose of this sampling will be to confirm the performance of the stormwater treatment system, to estimate the nutrient loads entering the lake in runoff and to detect any toxic or hazardous materials in the runoff.

The stormwater samples will be analysed for:

- pH, EC, TSS
- Hardness (as $CaCO_3$)
- Nutrients: TP, FRP, NO_X, TKN
- Heavy Metals: Al, As, B, Cd, Cr, Cu, Fl, Pb, Mn, Ni, Zn
- Microbial: faecal (thermotolerant) coliforms, enterococci
- Total petroleum hydrocarbons (TPH).

The stormwater sampling results will be compared with the ANZECC (2000) water quality guidelines for secondary contact recreational waters. If the level of any key parameter exceeds the guidelines on two consecutive occasions, investigations and/or contingency actions will be implemented as described in Section 8.2.2.

7.2.3 Lake Monitoring

The main lake will be monitored at a high frequency to ensure water quality is maintained at the standard necessary for secondary contact recreational use, as stated in ANZECC (2000). Samples for biochemical and microbiological analysis will be collected from the water surface, mid water and the bottom layer at three locations around the edge of the feature lake and one location in the irrigation lake, as shown on Figure 26. In addition, *in situ* water column profile measurements will be made from a dinghy at three locations in the feature lake and one in the irrigation lake (Figure 26).

The lake water will be monitored for the following parameters:

- pH, EC, DO, temperature, redox potential, turbidity (*in situ* profile measurements)
- Light Penetration (PAR)
- Total and Dissolved Iron
- Hardness (as $CaCO_3$)
- Nutrients: TP, FRP, NO_X, TKN, NH_4-N, Dissolved Organic Phosphorus, Dissolved Organic Nitrogen, Dissolved Organic Carbon, Particulate Organic Phosphorus, Particulate Organic Nitrogen, Particulate Organic Carbon
- Heavy Metals: Al, As, B, Cd, Cr, Cu, Fl, Pb, Mn, Ni, Zn
- OC and OP pesticides
- Microbial: faecal (thermotolerant) coliforms, enterococci
- Chlorophyll-*a* and Phaeophytins
- Total petroleum hydrocarbons (TPH).

Microbial and algal monitoring will be conducted quarterly for the first two years after establishment. This will be increased to monthly monitoring after about two years, when the lake becomes full and the opportunity for human contact with the lake water increases. If monthly monitoring indicates at any stage that algal or microbial populations are becoming elevated, the monitoring of these parameters may be increased to fortnightly until levels fall. All other water quality monitoring will be conducted quarterly for the first year after establishment and then six-monthly in subsequent years. The lake will also be sampled immediately after any significant stormwater overflow into the lake.

The lake water sampling results will be compared with the ANZECC (2000) water quality guidelines for secondary contact recreational waters and irrigation. If the level of any key parameter exceeds the guidelines on two consecutive occasions, investigations and/or contingency actions will be implemented as described in Section 8.2.3.

7.3 Algae Monitoring

The detection of algal growth will be measured in two ways: visually and through water sampling. The presence of algal growth (discolouration) in the lake will be monitored through frequent visual inspection by maintenance staff. Visual inspection will be undertaken in conjunction with other routine maintenance activities. Continuous public surveillance of the lakes will also be accessed by monitoring public correspondence regarding algae.

Chlorophyll-*a* concentrations and algal levels will be analysed as part of the lake water quality monitoring. These parameters will give an indication of the presence and abundance of algae in the lake.

The algal sampling results will be compared with the ANZECC (2000) water quality guidelines for secondary contact recreational waters. Should algal growth exceed trigger levels (Section 8.3) a sample will also be taken to identify the algal species present. This will focus particularly on the possible presence of cyanobacteria (blue-green algae), which in high concentrations may have toxic effects on humans and animals.

7.4 Aquatic Plant Monitoring

The primary means of monitoring and detecting weed growth in the lake will be regular visual inspection by maintenance staff. As weed growth is primarily a visual aesthetic problem, it is best and most easily monitored by visual means.

Rooted aquatic plants grow slowly by comparison with algae. Six-monthly visual inspection is considered sufficient to detect and remedy problems, although in reality the visual monitoring will be undertaken much more frequently than this in conjunction with other routine maintenance activities.

Continuous public surveillance of the lakes will also be accessed by monitoring of public correspondence regarding the lakes.

Should aquatic plant growth become a problem, particularly in regards to causing obstructions within the lake, then contingency measures will be implemented as detailed in Section 8.4.

7.5 Fish and Water Bird Monitoring

Monitoring of nuisance fish will be undertaken by visual inspection in conjunction with other routine maintenance activities. Fish sightings reported by the public will also be used to detect and anticipate fish population problems in the lake.

Should nuisance fish be noted within the lake then contingency measures will be implemented as detailed in Section 8.5.

Monitoring of bird numbers and presence of any introduced species will be undertaken by regular visual inspection in conjunction with other maintenance and monitoring activities. Any sightings or evidence of bird feeding will also be noted. Monitoring of public correspondence will supply information on any problems associated with bird numbers.

Should bird feeding or excessive numbers of water birds be noted and subsequent adverse conditions affect the lake, then contingency measures will be implemented as described in Section 8.6.

7.6 Insect Monitoring

Regular visual monitoring of insect numbers at the lake will be undertaken in conjunction with other regular monitoring and maintenance activities. Public correspondence will also be monitored as an important source of information on the level of insect nuisance, if any.

Quantitative mosquito larvae monitoring will be undertaken regularly in the lake. Samples will be collected with a scoop net at about eight locations around the lake edge and the number of larvae counted.

Mosquito monitoring will be carried out monthly between January and August each year. In the critical mosquito breeding period of September-October the monitoring will be carried out weekly, while during the sub-critical early summer period (November-December), the monitoring will be carried out fortnightly.

If the number of larvae in two adjacent sampling locations (or four locations in total) exceeds 50 on two successive sampling occasions, the Shire of Murray will be advised and contingency actions implemented as described in Section 8.7.

Full details of the mosquito monitoring programme and contingency responses are provided in the Mosquito Management Plan (RPS, 2007).

7.7 Reporting and Performance Review

The results of the lake monitoring program will be reported annually to the Shire of Murray, the DEC and the DoW. The reporting will cover water quality, abstraction and drawdown in the water supply bore (required for groundwater licence renewal), water quality and quantity entering the lake from bores, rainfall, roof runoff and stormwater, quantity of overflows from the lake, water quality in the lake, plus the results of monitoring of aquatic plants, algae, fish, water birds and insects.

A Performance Review Program (PRP) will be implemented based on the results of the monitoring, to gauge the success of the lake in meeting the stated objectives in terms of water use efficiency, water quality and social amenity. The PRP will operate continuously from the completion of filling of the first stage of the lake, and will address:

- actual versus modelled rainfall, roof runoff, storm inflow, overflow, irrigation outtake and evaporation;
- actual versus modelled in-lake water quality;
- actual versus predicted bird numbers, insect density, plant growth and fish populations; and
- observed public usage and amenity, records of public complaints and feedback, and records of any problems including closures, leaks and algal blooms.

The monitoring results will be used to periodically re-run the water balance and water quality models. The results of the remodelling will be included in the annual reports.

A performance review of the first stage of the lake will be undertaken prior to the construction of the second stage, in order to identify any modifications necessary to optimise water use efficiency, water quality or amenity. At this stage the performance review will be incomplete because several components of the water balance – including roof runoff, irrigation outtake and overflow – will be operating only partially or not at all, while the short period before the review (about two years) will be insufficient for the water quality, chemistry and biology of the lake to stabilise. Nevertheless, the early performance review will enable any major deficiencies or inaccuracies (including significant discrepancies in groundwater quality, roof runoff, stormwater inflow or water quality) to be identified and corrected before the second stage is constructed.

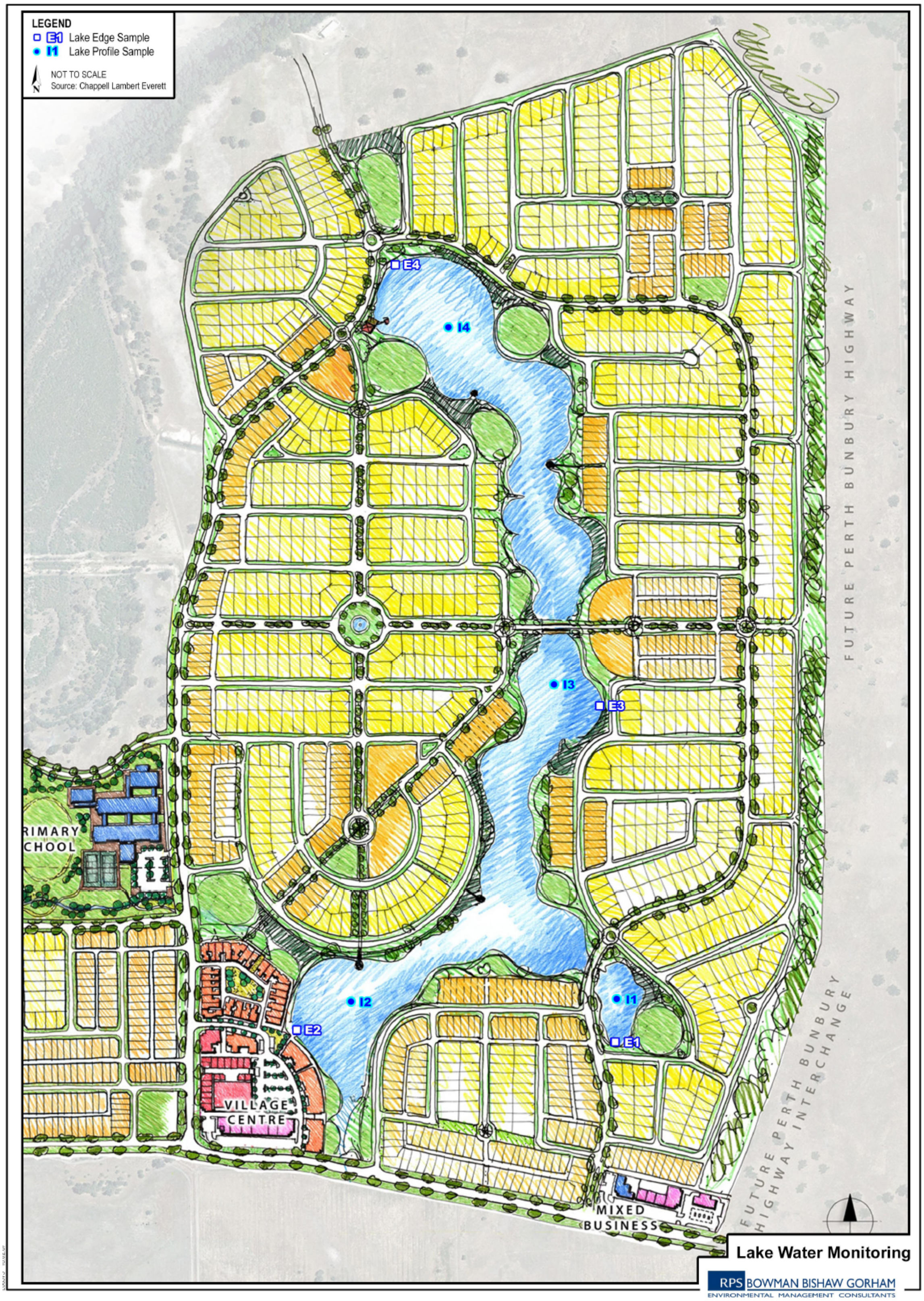


Figure 26 Lake Water Monitoring Locations

8.0 CONTINGENCY RESPONSE

8.1 Water Levels and Water Balance

A drop in lake water level may occur as a result of failure of the bore pumps, while an excessive consumption of groundwater for lake top-up may indicate a leak in the liner.

In the event the bore pump fails, the water level in the lake may temporarily fall below the intended minimum water level of 2.2m AHD. This may cause stress to riparian reeds and other aquatic flora planted around the lake edges. This stress will be minimal if the water level is only below the minimum for a short period.

In the event that the groundwater pumps fail, they will be repaired or replaced as quickly as possible. Some reaction time is available due to the large volume of water in the lake.

If a drop in water level appears likely to cause stress to vegetation around the lake margins, temporary irrigation may be carried out as part of the landscape maintenance regime until the water levels are back within the nominal range.

8.2 Water Quality

8.2.1 <u>Bore Water</u>

If any bore water quality parameter significantly exceeds the pre-development value or the ANZECC (2005) guideline for secondary contact recreational waters on two consecutive sampling occasions, contingency measures will be employed.

Initially the Shire of Murray will be notified and an investigation will be undertaken to establish the likely cause of the exceedence, the likely impacts and the available remedies.

Contingency measures available in the event of deterioration in bore water quality will include:

- treatment of bore water before discharge into the lake (depending on the nature of the contamination);
- identification of an alternative source of bore water; and
- “shandying” of bore water with scheme water for irrigation.

8.2.2 Stormwater

Frequency and Volume

If the frequency or quantity of stormwater overflow into the lake significantly exceeds predictions, greater than expected loads of nutrients and other contaminants may enter the lake, leading to poorer than expected water quality. In the event of greater than expected stormwater inflows, lake sampling and modelling will be used to determine whether it is having an adverse effect on water quality. If so, contingency measures available will include:

- cleaning of infiltration basins to remove accumulated sediments;
- enlargement of basins (if feasible) to increase storage capacity and detention time;
- increased public education efforts to reduce the level of contamination in the catchment.

Water Quality

The water quality of urban runoff varies widely both spatially and temporally; first flush runoff can contain levels of some pollutants as high as sewage. While such first flush runoff will be captured by the infiltration basins and will not reach the lake, it is nevertheless likely that stormwater overflow may exceed at least some water quality guidelines for recreational waters. Contingency actions in this case will focus on responding to the presence of any toxic or hazardous materials (e.g. hydrocarbons, heavy metals, pesticides, micro-organisms) or nutrient levels high enough to significantly impair the water quality of the lake.

In the event that storm event sampling detects levels of toxic or hazardous material at levels above the ANZECC (2000) guidelines or excessive levels of nutrients, the following contingency actions will be taken:

- The Shire of Murray will be notified immediately.
- The lake will be closed to contact recreational use.
- Lake samples will be collected to determine whether the contaminant(s) are present in the lake in sufficient quantities to cause concern.
- An investigation will be undertaken in the catchment to identify and rectify the source of the contamination.
- The lake will only be reopened for recreation when sampling shows that the levels of all parameters meet the ANZECC (2000) guidelines for secondary contact recreational waters.

Longer-term contingency actions available to improve the quality of stormwater overflows will include:

- cleaning of infiltration basins to remove accumulated contaminants;
- enlargement of infiltration basins to increase storage and detention capacity;
- increased street cleaning frequency to reduce the contaminant load of stormwater;

- increased public education efforts to reduce the level of contamination in the catchment; and
- prosecution of persons found to be illegally discharging contaminants in the catchment.

8.2.3 Lake Water

If any water quality parameter in the lake breaches the ANZECC (2000) guidelines for secondary contact recreational waters on two successive sampling occasions, the Shire of Murray will be notified and an investigation undertaken to establish the likely cause of the exceedence, the likely impact and the available remedies.

If an exceedence of microbial or algal contamination guidelines is identified or if hazardous material is detected in the lake, a repeat sampling will immediately be carried out. If this repeat sampling confirms the exceedence, the lake will immediately be closed to recreational use until further sampling shows that the water quality meets the guidelines. The closure of the lake will be notified by means of signs erected at regular intervals around the lake, which will explain the reasons for the closure and provide a contact number for further information.

In the longer term, contingency measures available to deal with poor water quality in the lake could include:

- control of bird numbers to limit faecal nutrient inputs (see Section 8.5);
- reduction in storm overflow volumes, frequency or contaminant levels by the means discussed in Section 8.2.2; and
- in the worst case, seasonal or even permanent closure of the lake to contact recreational use.

Contingency measures relating specifically to controlling excessive algal growth are discussed on Section 8.4.

8.3 Lake Stratification

Strong and prolonged stratification, especially during the spring-summer period, needs to be avoided as it can give rise to algal blooms and the release of phosphorus from sediment. The results of the lake temperature and dissolved oxygen monitoring will be used to assess the occurrence and degree of stratification. If stratification occurs, contingency actions available to aerate the water column include:

- Use of aerators/bubblers located at the bottom of the lake to assist in water circulation and increase dissolved oxygen concentrations.

- Use of circulation pumps to promote horizontal and vertical mixing of the lake. The mixing will increase the concentration of dissolved oxygen in the deeper layers and reduce the growth of blue-green algae.

- In the unlikely event that severe stratification occurs, both induced mixing and direct aeration of the bottom layers can be used together to aerate and mix the water.

8.4 Algal Growth

In addition to algal control through water quality management measures, a number of direct control methods are available to manage algal growth. Some of these are summarised below.

- Mechanical harvesting and removal of algae from the water body can remove excessive build-ups of filamentous algae and remove nutrients from the lake. This technique is only effective in the case of very heavy algal accumulations and is unlikely to be useful against blue-green and other suspended single-celled algae.

- Algaecides are very effective in the short term against a wide range of algae. Algaecides based on chelated copper, bromine or quaternary ammonium compounds are commonly used to control algae in swimming pools and are safe for secondary-contact recreational waters. In summer, when there is no outflow from the lake, these agents may be feasible to use for algal control in the lake if necessary. However, given that the lake is expected to overflow in winter, their safety in the receiving waters of Peel Inlet would need to be demonstrated before they were used.

- Barley straw, when rotting in water, has been shown to produce an enzyme that acts as a natural algaecide. Barley straw has been used successfully to treat algal growth in irrigation storage ponds at Mandurah Quay Resort (A. Lynch, Mandurah Quay, pers. comm. 1998). It has been less successful in other cases including lakes at Bridgewater South, Erskine and Hillarys Boat Harbour. Its disadvantages include the need to use a relatively high density of straw bales, the need to replace the bales at intervals of every 6-8 weeks and the tendency of the bales to produce significant amounts of floating straw litter. A commercial product developed by Frogmat Environmental (www.frogmat.co.uk/applications) can be used to replace the straw bales with, presumably, less liberation of straw litter.

- Ultrasonic devices can be used to directly kill algae. One product available locally, the Waterman Algae Controller, uses ultrasonic pulses to rupture the vacuoles (air pockets) in algal cells, causing the cells to die. The Waterman system has been successfully employed in several locations including the WA Police Academy, the Joondalup campus of Edith Cowan University and the City of Joondalup (BBG, 2001).

- Colouring agents such as the commercial product Aquashade can be added to the lake water to reduce the amount of sunlight available to algae, thereby limiting growth. This could be feasible in the feature lake in summer when turnover is low, although the quantity required would be large and the resultant intense (usually blue) colour may be considered undesirable.

- Chemical treatment may be used to reduce internal phosphorus loadings by precipitating and binding phosphorus in the sediments. Materials possibly suitable for this include red mud (bauxite residue) and lanthanum-based pool treatment chemicals.

- Macrophytes such as water lilies, Typha and other species may be introduced to reduce light penetration, limit wind-induced sediment disturbance, provide refuge for algal grazing zooplankton such as *Daphnia* and compete directly with algae for nutrients. However, they may also promote anoxia of the deeper water, reduce circulation and create an obstruction to water craft and in-lake equipment.

8.5 Aquatic Plant Growth

Contingency measures will be implemented if aquatic plant growth reaches undesirable levels or if public complaints regarding excessive plant growth are received.

Contingency actions available include the following:

- Heavy growths of plants may be physically harvesting and removed from the lake. This would have the added advantage of removing stored nutrients from the lake. This is a temporary measure that would only be contemplated in the event of very heavy plant growth that was causing other undesirable effects on the lake, such as water quality problems or interference with recreational activities or equipment.

- Colouring agents such as Aquashade may be added to the water to reduce the amount of sunlight available to aquatic plants. The strategy has disadvantages of cost (due to the volume to be treated) and production of an artificial water colour.

- Herbicides may be used to directly kill or inhibit the growth of macrophytes. This would be an option of last resort and would depend on the availability of a product that was short-lived and safe to be discharged into the receiving environment.

8.6 Water Birds

Contingency measures will be implemented if routine monitoring detects excessive numbers of birds, introduced species, bird deaths or bird feeding, or if public complaints regarding birds are received.

Contingency actions available to deal with excessive bird numbers include:

- increased public education and signage advising against feeding;
- introduction of bird-scaring devices such as raptor and snake silhouettes; and
- capture and removal of feral birds (e.g. mallards and domestic ducks) and aggressive birds such as black swans and feral geese.

8.7 Nuisance Fish

Contingency measures to control fish may be implemented if routine monitoring detects signs of nuisance fish presence or if public complaints regarding fish are received.

Practical contingency actions available to deal with fish include netting and electric stunning. More extreme measures such as draining the lake are unlikely to be required.

8.8 Insects

Full details of the mosquito monitoring programme and contingency responses are set out in the Mosquito Management Plan (RPS, 2007). A brief summary is provided below.

If the number of live mosquito larvae collected exceeds 50 per 250ml sample at two adjacent sampling locations (or four locations in total) on two successive sampling occasions, the Shire of Murray will be notified and a contingency response developed in consultation with Shire environmental health officers.

The contingency actions available will include:

- cleaning of gross pollutant traps, trash racks and other drainage structures to reduce water accumulation;
- thinning of in-lake vegetation (including sedges) to reduce breeding habitat;
- modification of the lake to remove identified breeding areas;
- chemical control such as the larvicide s-methoprene, as currently used by the Shire;
- biological controls including introduction of insectivorous fish and planting of lemon grass near inhabited areas;
- passive controls such as modification of park lighting near areas frequented by visitors.

9.0 MANAGEMENT AND MAINTENANCE COSTS

9.1 Monitoring Costs

Table 9.1 summarises the expected costs of regular monitoring of bore water, lake water and ancillary items. The costs are based on typical contractor and analytical laboratory rates and are expressed in 2007 dollars.

Table 9.1 Summary of Lake Monitoring Costs

Parameter	*Source/Method*	*Frequency*	*Average Annual Cost*
Inflows and Outflows Bore inflows Irrigation outflows	Pump operating records	Recorded continuously Audited annually	$450
Overflow volume	Water level recorder on overflow weir	Recorded continuously Audited annually	$450
Rainfall and evaporation	Bureau of Meteorology / Dept of Agriculture	Obtained annually	$150
Bore Water Quality pH Salinity (TDS) Total & dissolved Iron Hardness (as $CaCO_3$) Total P Reactive P Total Kjeldahl Nitrogen Nitrite + Nitrate Ammonia-N Heavy metals: Al, As, B, Cd, Cr, Cu, Fl, Pb, Mn, Ni, Zn	Water supply bore(s)	**First Year:** • Dec, Mar, Sept, May **Subsequent Years:** • Mar, Sept **Salinity only:** • Monthly Sept-May (first year)	**Years 1-2:** $975 collection $1,200 analysis **Subsequent Years:** $300 collection $600 analysis
Stormwater Inflow Quality pH, EC, TSS Hardness (as $CaCO_3$) TP, FRP, NO_X, TKN, NH_4-N Heavy metals: Al, As, B, Cd, Cr, Cu, Fl, Pb, Mn, Ni, Zn Faecal coliforms, enterococci Total Petroleum Hydrocarbons (TPH)	Inflow points (13): grab samples and/or rising stage samplers	Opportunistic – average once every 5 years	$240 collection $880 analysis

Lake Water Quality Total P Reactive P Dissolved Organic P Particulate Organic P Total Kjeldahl N Nitrite + Nitrate Ammonia-N Dissolved Organic N Particulate Organic N Dissolved Organic Carbon Particulate Organic Carbon Total & dissolved Iron Hardness (as $CaCO_3$) Heavy Metals: Al, As, B, Cd, Cr, Cu, Fl, Pb, Mn, Ni, Zn Faecal coliforms, enterococci Chlorophyll-*a* Phaeophytins OC & OP pesticides TPH	Lake edge sampling locations (4)	**First Year:** • Dec, Mar, Jun, Sept **Subsequent Years:** • Mar, Sept **Microbial and chlorophyll:** • Dec, Mar, Jun, Sept (first and second years) • Monthly (subsequent years) Plus event sampling after stormwater inflows (average once every 5 years)	**First Year:** $7400 collection $6560 analysis **Second Year:** $3800 collection $4180 analysis **Subsequent Years:** $3800 collection $7800 analysis
Temperature pH Salinity (EC) Turbidity/Light Penetration Dissolved oxygen Redox potential	Lake profile locations (4) from dinghy		
Algae	Visual surveillance	Six monthly	$150
	Chlorophyll-*a* monitoring	As for lake water quality	
Aquatic Plants	Visual surveillance	Six monthly	$150
	Public correspondence	Continuous	$150
Fish	Visual surveillance	Six monthly	$150
	Public correspondence	Continuous	$150
Birds	Visual surveillance	Six monthly	$150
	Public correspondence	Continuous	$150
Insects	Visual surveillance	Six monthly	$150
	Public correspondence	Continuous	$150
	Larval counts	Monthly Jan-Aug Weekly Sep-Oct Fortnightly Nov-Dec	$12,000
Estimated total annual cost	- **Year 1**		**$31,650**
	- **Year 2**		**$24,400**
	- **Subsequent Years**		**$28,000**

9.2 Infrastructure Maintenance Costs

Table 9.2 summarises the infrastructure maintenance tasks and estimated annualised costs, based on information provided by equipment suppliers.

Table 9.2 Summary of Infrastructure Maintenance Costs

Item	*Scheduled Maintenance*	*Annual Cost*
Bore pumps	Annual inspection & service 10 yr overhaul	$3,500 per pump x 3 when lake fully constructed
Circulation pumps	Annual inspection & service 10 yr overhaul	$3,500 per pump x 4 when lake fully constructed
Intake screens	Annual inspection & service	$5,500 per pump x 2 when lake fully constructed
Pump pit	Annual inspection & service	$1,500
Pump support frames	Annual inspection & service	$500
Aerators	Annual inspection & service 5 yr overhaul	$1,000 per aerator
Timber decking	Annual recoating	$5 per m^2, assuming 1,000m^2 = $5,000
Litter removal	Fortnightly	$500 per event @ 26 events per year = $13,000

10.0 IMPLEMENTATION

Satterley Property Group will implement and wholly fund the Lake Management Plan for at least ten years after practical completion of the lake or until the completion of Austin Cove Phase 2, whichever is the later. At the end of this period, the ownership and responsibility for management of the lake will be transferred to the Shire of Murray.

Satterley Property Group will establish a funding mechanism in consultation with the Shire of Murray to cover the ongoing projected costs of lake monitoring, management and maintenance, as detailed in Section 9.0, following the handover of the lake to the Shire. This funding mechanism is envisaged to be based on a Specific Area Rate levied by the Shire of Murray on lot owners within Austin Cove. Satterley will continue discussion with the Shire of Murray over the form, scale and implementation of the funding mechanism.

11.0 REFERENCES

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Appendix A

Documentation Relating to PVC Liner Material

Appendix B

Hydrodynamic Modelling

Appendix C

Water Balance and Nutrient Modelling